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Workshop Report On Virtual Worlds and Immersive Environments

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Report of a workshop
sponsored by and held at
NASA Ames Research Center
Moffett Field, California
on January 26-27, 2008

May 2009

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Executive Summary

On January 26th and 27th, 2008, NASA Ames Research Center hosted a two-day weekend workshop entitled *Virtual Worlds and Immersive Environments*. The purpose of this two-day conference was to explore where virtual world technology can be taken, and how it can be leveraged in the short and medium term to support and advance space exploration and settlement. Ideally, it will further NASA's goals to facilitate communication and connections both within NASA and with educators, students, and the public by using immersive environments and virtual worlds.

The workshop was organized around three themes, the first of which is **remote exploration** or the ability to create high-fidelity environments rendered from external data so that exploration, design, and analysis can take place within them. This enables the creation of simulations in virtual worlds that are valuable for exploring mission concepts such as lunar architectures and human missions to Near Earth Objects, or for training astronauts to work on the Space Shuttle or International Space Station (ISS). Two simulations that have already been developed are SimConstellation that runs various lunar mission scenarios using the new Constellation hardware, and SimStation, which is a tool that simulates the operation of the ISS with sufficient fidelity to make behavioral trade studies. Simulations also have considerable potential for education and entertainment. Several educationally oriented simulations were described at the workshop, such as LUROVA, which is an Apollo lunar roving vehicle simulation being developed for students.

The ultimate goal is to have all NASA data in immersive interactive virtual worlds. High-resolution data can significantly improve the fidelity and usefulness of platforms such as Google Earth and Google Mars. These platforms make NASA's imagery and geospatial information universally and easily accessible. The importance of open standards and network interoperability was stressed. This is a requirement for creating rich media and three-dimensional (3D) graphics, and distributing that content over a wide range of platforms.

The second theme of the workshop was **we all get to go**. The focus is on developing new paradigms for education, outreach, and the conduct of science in society that is truly participatory. While generations have been fascinated by science fiction through books, magazines, and movies, the availability of Massively Multiplayer Online (MMO) games offers a new media for engagement. Will Wright, the creator of "SimCity" and "The Sims" described a new MMO game *Spore™* that allows a player to control the evolution of a species. The game promotes creativity and imagination and has considerable educational potential. The *Lunar Racing Championship* MMO created by Virtue Arts tries to create excitement by racing on the Moon. The game simulates both the reduced gravity and terrain of the Moon. Another innovative educational approach is the SciFair model deployed in SciCenter at Cornell University. It leverages the multiplayer game environment to present educational science content and simulations in a safe social setting. The first step is for the students to master the technology of virtual worlds, and then secondly to perform a team-based science project.

Immersive synthetic environments have qualities like built in engagement, fast feedback, cognitive outsourcing, and easy repetition that make them excellent tools for promoting learning. Virtual worlds such as Second Life can promote distance learning and collaboration. This was illustrated by the Pacific Rim Exchange Project, which is a foreign exchange program being carried out in *Second Life* between Modesto city schools and Kyoto Gakuen high school in Japan. Four islands were shared on the Teen Grid in *Second Life*. Cultural exchange was facilitated through organized island events (in *Second Life*). The students were highly engaged, which shows that virtual worlds can play an important role in the future of education. An institution that is on the leading edge of promoting education through virtual worlds is the Exploratorium in San Francisco. The Exploratorium showed the 2006 solar eclipse from Turkey in *Second Life*, and it has a large number of exhibits in 'Splo,' *Second Life*'s interactive museum of science, perception, and art.

The third theme of the workshop was **become the data**, a vision of a potential future where boundaries between the physical and virtual worlds cease to be meaningful. One manifestation is telepresence or the feeling of being present, yet remotely located. This is becoming increasingly possible due to high-speed, fiber-optic links between locations. For example, the global LambdaGrid cyber infrastructure that connects university research centers at 10 gigabytes per second enables persistent high-performance collaborations on a global scale. Ongoing projects such as the OptIPuter, whose goal is to create high-resolution portals over dedicated optical channels, will achieve telepresence by enabling the sharing of large data sets worldwide. Workshop participants advised NASA to begin planning the infrastructure for broadband multidimensional data in time to make the exploration of the Moon a milestone in virtual presence.

Another consequence of the blurring of boundaries between physical and virtual worlds is the ability to perform useful simulations in virtual worlds. For example, a simulation of Unimodal's SkyTran System in *Second Life* gave useful design information from a human factors perspective, even though the physics was not of high fidelity. Virtual worlds also augment collaboration in other ways, for example, meetings in *Second Life* using text chat tools can offer an alternative to video conferencing or web-based teleconferencing.

Spatial immersive displays may enable delivering a scientifically accurate virtual universe to the masses. Spatially augmented reality technologies may ultimately allow us to interact directly with data using natural gestures. Effort is ongoing to create a network of domes to enable the production and exchange of very-high-quality digital media over photonic networks (a communications network in which information is transmitted entirely in the form of optical or infrared transmission signals.)

Virtual worlds are in a period of rapid expansion, much like what occurred with the World Wide Web more than a decade ago. Clearly, virtual world technologies have significant application to NASA operations and educational outreach. It is hoped that this workshop will help begin the process of developing a strategy for incorporating these new technologies into future NASA missions.

Workshop Report On
Virtual Worlds and Immersive Environments

Stephanie Langhoff[1], Jessy Cowan-Sharp[2], Estelle Dodson[3], Bruce Damer[4], Bob Ketner[5], Joseph Minafra[3], and Debbie Denise Reese[6]

Ames Research Center

I. Introduction

A workshop entitled "Virtual Worlds and Immersive Environments" was held at Ames Research Center (ARC) on 26–27 January 2008. This workshop is part of a series of informal weekend workshops initiated and hosted by the Ames Center Director, Dr. Pete Worden. The organizing committee included Stephanie Langhoff (Chair), Jessy Cowan-Sharp, and Estelle Dodson of Ames Research Center; Bruce Damer of DigitalSpace Corporation; and Bob Ketner of Studio SFO. Sixty-nine persons representing government, industry, and academia attended.

The workshop revolved around three framing ideas or scenarios about the evolution of virtual environments:

1. **Remote exploration:** The ability to create high fidelity environments rendered from external data or models such that exploration, design and analysis that is truly interoperable with the physical world can take place within them.
2. **We all get to go:** The ability to engage anyone in being a part of or contributing to an experience (such as a space mission), no matter their training or location. It is the creation of a new paradigm for education, outreach, and the conduct of science in society that is truly participatory.
3. **Become the data:** A vision of a future where boundaries between the physical and the virtual have ceased to be meaningful. What would this future look like? Is this plausible? Is it desirable? Why and why not?

This workshop focused specifically on the convergence of the underlying technologies necessary to achieve high-fidelity, virtual environment experiences and possible architectures. There was an emphasis on how these technologies can support scientific and engineering visualization and analysis, and how they could support and augment the National Aeronautics and Space Administration (NASA) mission.

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Invited lecturers guided workshop participants in an exploration of these ideas or scenarios by hypothesizing the potential future of each. Other talks focused on the more immediate, substantive topics of architecture, toolsets, features, applications, and hardware. Ample discussion time was included in the program to maximize interaction among participants.

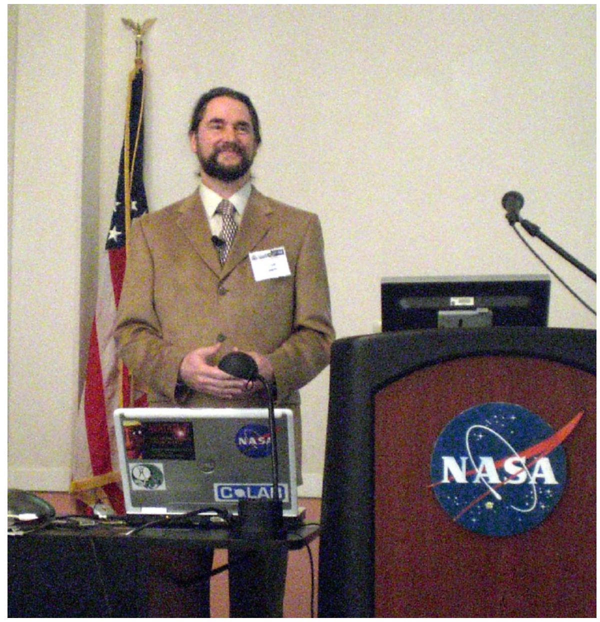
The final afternoon was devoted to interactive discussions, organized around three specific questions: (1) How could we best use virtual world environments to support Lunar Crater Observation and Sensing Satellite (LCROSS) and other near-term NASA missions? (2) What can NASA do to create a viable community of people and organizations developing virtual world technologies for space? and (3) How will virtual worlds be used in the exploration of space in the year 2020? The program ended with a discussion of research priorities and follow-up actions.

View of the workshop attendees (Photo courtesy of Bruce Damer)

II. Remote Exploration

II.1 Virtual World Applications

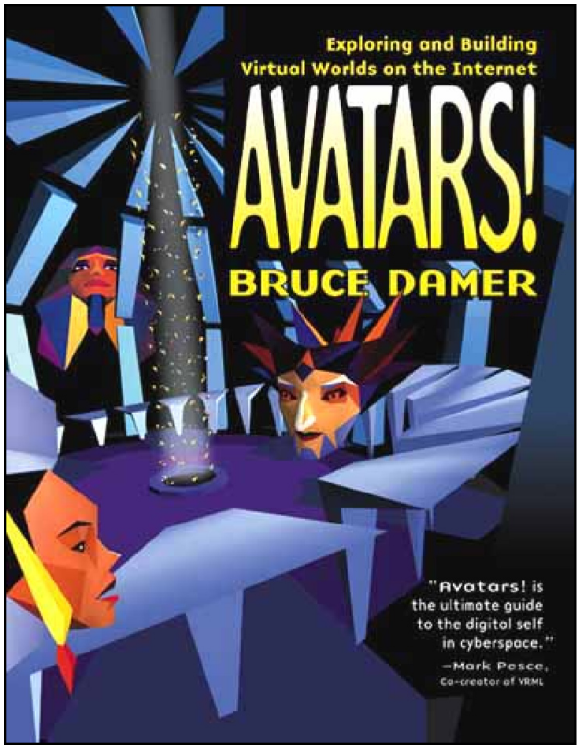
Bruce Damer of Digital Space (http://www.digitalspace.com/) began the workshop with a paper entitled "Cyberspace Meets Outerspace" that provided an excellent overview of the development of virtual worlds. He described this from the point of view of an imaginative young boy interested in both virtual worlds and space exploration, who grew up watching astronaut Rusty Schweichart launch into space on Apollo IX, and sketching alien worlds and weird spacecraft.



Bruce Damer presenting the opening session (Photo courtesy of Bruce Damer)

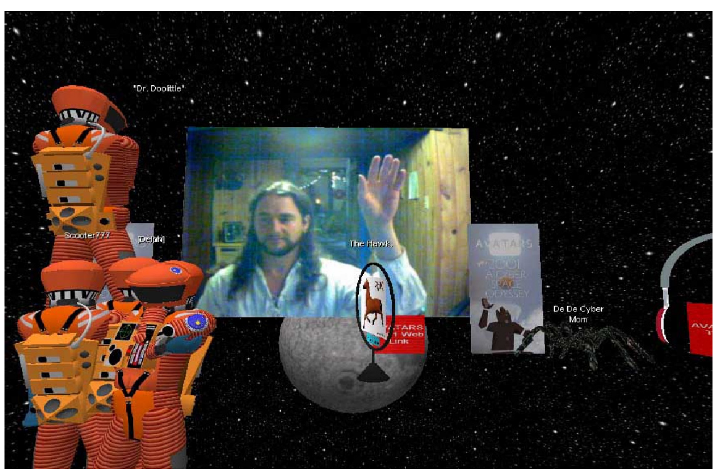
Bruce Damer's involvement in virtual worlds began in the early 1990s with the creation of the Contact Consortium and DigitalSpace organizations. In May 1995, Worlds Chat, the first "avatar" virtual world arrived on the Internet in the form of a space station. In this workshop report we use the term "avatar" to refer to a computer user's representation of himself or herself, either in the form of a 3D model used in computer games or a 2D icon used on internet forums. The term was introduced in 1985 for Lucasfilm's *Habitat*, a virtual world running on the Commodore64 computer using dial-up connections. By the summer of 1995 it was now possible to teleport into the first user-built world, Alphaworld.

Apollo IX astronaut Rusty Schweickart in orbit in 1969 (Photo courtesy of Bruce Damer)



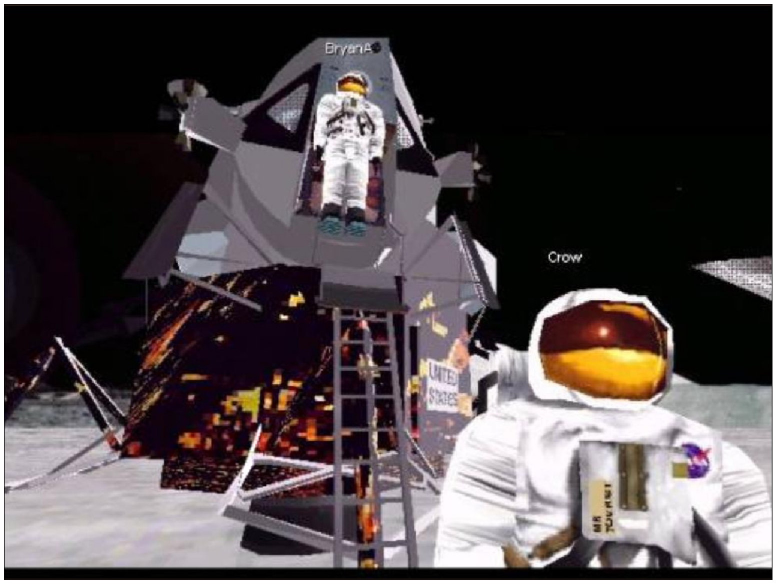
Cover of “Avatars”, Damer’s 1997 book on the subject (Photo courtesy of Bruce Damer)

Many books have now been written on the subject of avatars, but the first was Bruce Damer’s *Avatars!* (1997 Peachpit Press). The first conference dedicated to Avatars was produced and hosted by Bruce and his Contact Consortium in October, 1996.



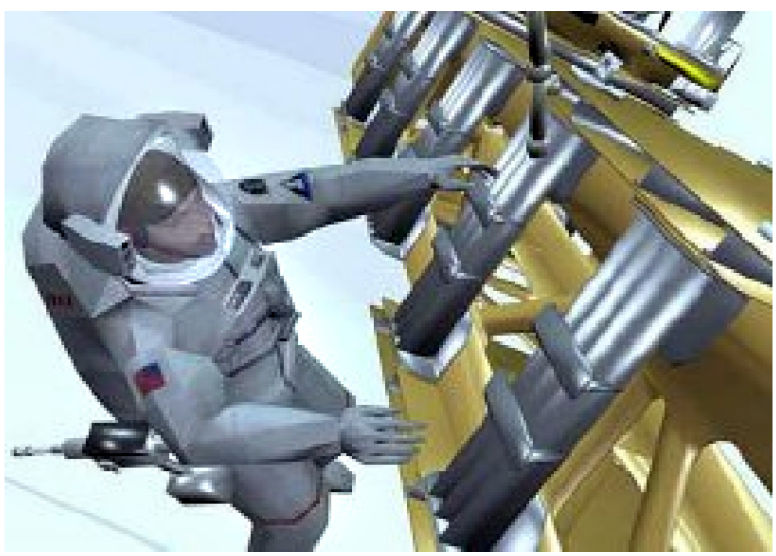
View of Avatars 2001, A CyberSpace Odyssey, a space-themed online conference—part of the 1996-2003 series by the Contact Consortium (Photo courtesy of Bruce Damer)

The first “cyber-conferences” (held inside avatar spaces) began in 1998 and many have taken on space themes.



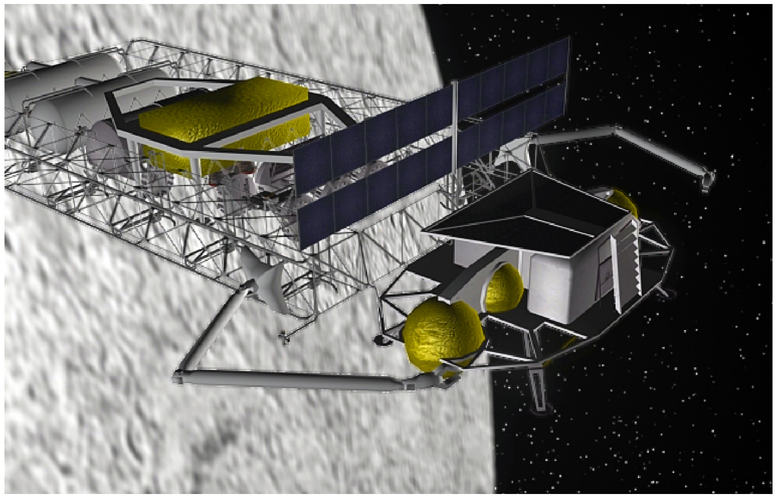
The “virtual walk on the moon” with Rusty Schweickart held in a virtual world in July 1999 (Photo courtesy of Bruce Damer)

In July of 1999, avatar cyberspace came together with outerspace when Bruce Damer and Rusty Schweickart re-enacted the first steps on the moon to mark the 30th anniversary of Apollo XI. This project piqued the interest of NASA scientists and led to Bruce’s company, DigitalSpace, winning support for many projects with NASA.



Simulation created for STS-114 Return to Flight mission (2005) (Photo courtesy of Bruce Damer)

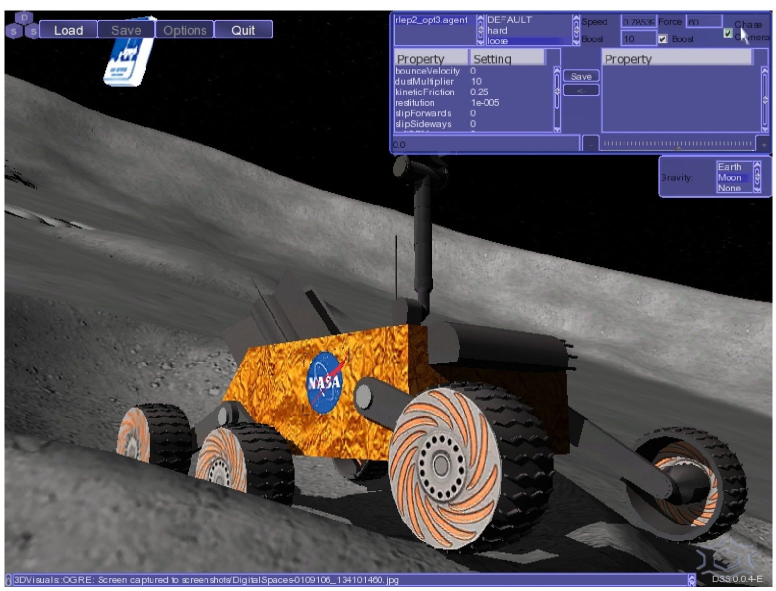
By 1999 it was clear that virtual worlds had real application to NASA’s mission. For example, one could create simulations in a virtual world for training astronauts to work on the Space Shuttle or the ISS.



Lunar telerobotic base construction—a concept study for Raytheon and NASA (2004) (Photo courtesy of Bruce Damer)

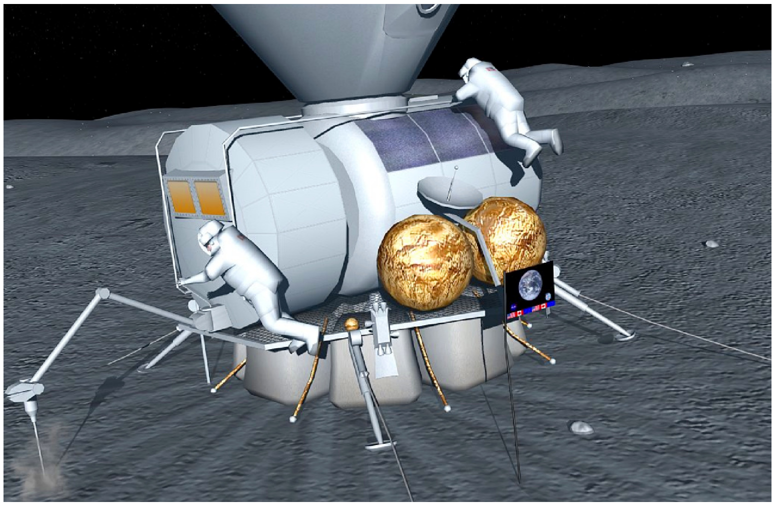
Simulations have been developed for full concept lunar architectures, for a bucket wheel excavator digging into the lunar regolith, and for in-situ processing of lunar materials.

A simulation has also been developed for landing the Lunar Surface Access Module (LSAM)/Altair lunar lander on the moon.



Lunar crater ice explorer rover for NASA (2005-2006)
(Photo courtesy of Bruce Damer)

Simulations have been carried out for landing in permanently lit areas on crater rims at the lunar poles, and then dispatching robotic vehicles to journey to the crater floors to drill for water ice. This work led to the design of a reference mission with Marshall Space Flight Center (MSFC), Jet Propulsion Laboratory (JPL), and Ames Research Center (ARC).



Constellation hardware concept study for crewed missions to near earth objects (NEOs) for NASA (2007) (Photo courtesy of Bruce Damer)

However, the most impressive simulation to date has been a human mission to a Near-Earth Object (NEO), which was used to study the feasibility of using Constellation hardware for a mission to an Earth-orbit crossing asteroid. (Constellation is a NASA program whose goals are gaining significant experience in operating away from Earth's environment, developing technologies needed for opening the space frontier, and conducting fundamental science.)

"DriveOnMars," a web-based virtual version of the Mars Exploration Rovers for public outreach (2004) (Photo courtesy of Bruce Damer)

Bruce also showed some of his company's public outreach projects including "Drive On Mars", a web-based Mars rover simulation launched at the same time as the Mars Exploration Rovers began their multiyear journey on the surface of Mars. Bruce then finished by saying that he hoped that the virtual world environments that his company created would inspire other children (like the seven-year-old Bruce) to pursue their dreams. He completed his onscreen demo with a view of the impressive International Spaceflight Museum and the NASA CoLab in *Second Life*.

International Spaceflight Museum in *Second Life*
(Photo courtesy of Bruce Damer)

II.2 Bringing Planetary Content into Virtual Worlds

Matt Hancher of NASA Ames spoke about his on-going effort to bring planetary content into virtual worlds. He is approaching the problem, both from the standpoint of bringing greater interactivity into large data sets, and by improving the content of simplified worlds whose strength is interactivity. His goal is to have all NASA data in immersive interactive virtual worlds. The NASA planetary data sets span data from the sun, for example, from the Solar and Heliospheric Observatory (SOHO) satellite, to the outer planets where the Cassini-Huygens spacecraft is sending back vast amounts of data. The data sets are large and expanding rapidly. For example, each Moderate Resolution Imaging Spectroradiometer (MODIS) captures approximately 100 gigabytes (GB)/day, or over 20 terabytes (TB) of data per year since the Terra and Aqua satellites went into service in 2000 and 2002, respectively. The Landsat program that consists of a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological survey captures ~320 GB/day. Data transfer from Mars is substantial also. The instruments on the Mars Reconnaissance Orbiter (MRO) will send 35 TB of data by mission completion, and the Lunar Reconnaissance Orbiter Camera (LROC) will transfer roughly 62 TB of data from one year of primary mission operations.

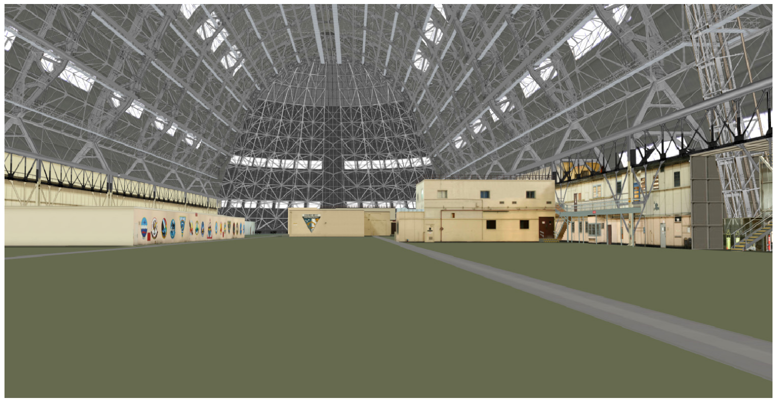
One of NASA Ames strengths is terrain reconstruction software, which was originally developed to support Mars lander missions, and then adapted for processing planetary imagery data using the Columbia supercomputer at ARC. It is now possible to construct accurate elevation models of Mars using data from the high-resolution spectrometers on board the orbiting satellites. For example, the High/Super Resolution Stereo Color Camera (HRSC) aboard Mars Express will image Mars in full color, in three dimensions, and at high resolution. Stereo images can be constructed from this data that dramatically improve the planetary content in platforms such as Google Mars.

This terrain reconstruction capability has led to a new planetary content collaboration with Google. The project has four high level goals: (1) Make NASA's Earth, Moon, and Mars imagery and geospatial information universally and easily accessible; (2) Showcase NASA's ongoing efforts and legacy of planetary science and exploration; (3) Target both the general public and scientists as users; and (4) Leverage open standards and the Google Earth platform. With this platform, browse and index tools can revolutionize the way Earth and planetary scientists locate data. Web-based collaborative content authoring tools improve the capability of both scientists and educators to quickly communicate geospatial ideas. It is now possible to create 3D virtual worlds with accurate geospatial data. Once these accurate virtual worlds are created, they can be used to carry out realistic mission operations. NASA is making their data accessible through open geospatial consortium web services such as OnEarth and with simple tiled web interfaces and Keyhole Markup Language (KML), a language schema for expressing geographic annotation and visualization on web-based 2D maps and 3D Earth browsers.

Important points emerging from his talk were that interactive 3D environments must be designed to support access to enormous data sets. Furthermore, NASA can do a better job of making its data available in formats that support a wider range of communities, and should even possibly be working toward a unified NASA Application Programming Interface (API).

II.3 X3D and Networked Interoperability

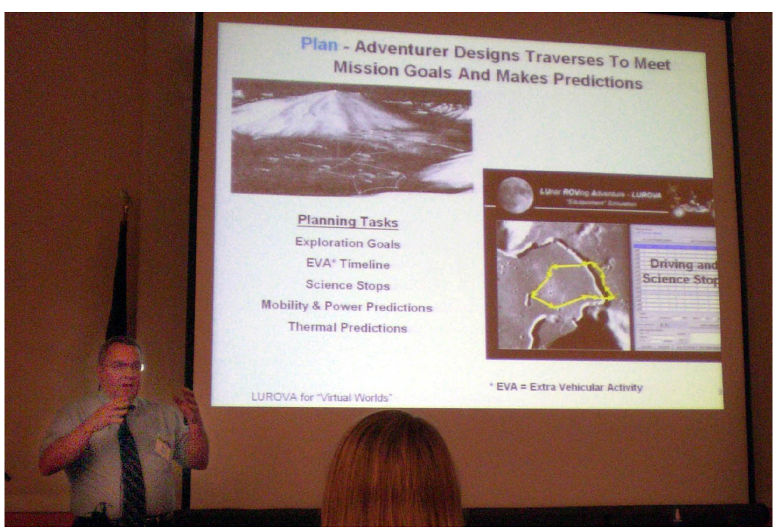
Alan Hudson, president of Yumetech, Inc. (www.yumetech.com), presented a paper entitled "X3D and Networked Interoperability." X3D is the International Organization for Standardization (ISO) standard Extensible Markup Language (XML)-based file format for representing 3D computer graphics standardized by the Web3D Consortium. It is an open standards file format and contains a run-time architecture. It features web optimized streaming and web integration. It provides a system for the storage, retrieval, and playback of real-time graphics content embedded in applications, all within an open architecture to support a wide array of domains and user scenarios. For example, in X3D Earth, the user can tailor their own planet using tools for terrain creation and viewing. This could be useful for mission planners who wanted to, for example, run simulations or look at terraforming scenarios. X3D is capable of creating rich media including 3D graphics and distributing that content over a wide range of platforms and networks.



X3D model of Hanger One at NASA ARC
(Photo courtesy of Bruce Damer)

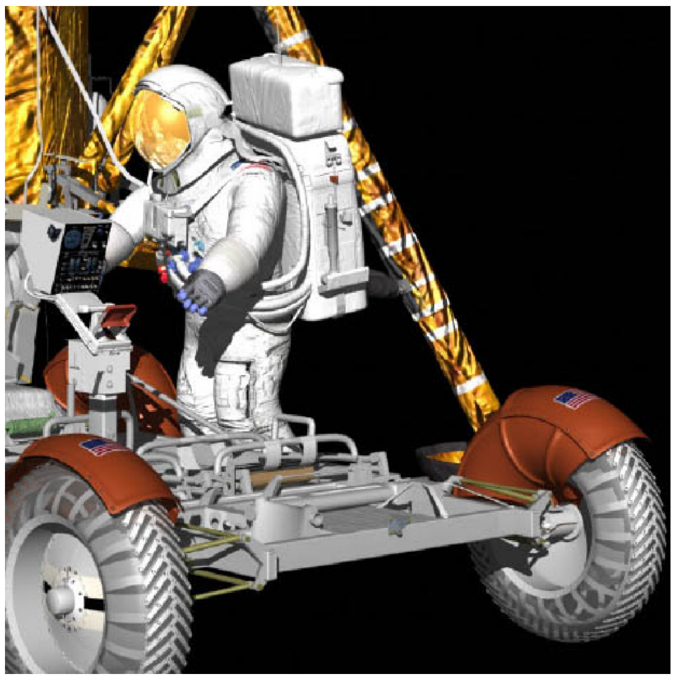
He also discussed briefly the issue of network interoperability. Although the small (<500 users) networking problem is solved, and while there are networking tools that support a larger number of users (e.g., *Second Life* and *There*), they are generally incompatible. This underscores the need for cross system standards, such as X3D and Collada. Collada defines an open standard XML schema for exchanging digital assets among various graphics software applications that might otherwise store their assets in incompatible formats. The combination of Collada for digital asset exchange and X3D for exchanging rich media makes for an open standards content path that should be examined for virtual worlds desiring the ability to create models and behaviors.

II.4 LUROVA: "Edutainment"



Ron Creel presenting LUROVA (Photo courtesy of Bruce Damer)

Ron Creel, former Apollo engineer, presented a paper entitled "LUnar ROVing Adventure (LUROVA)", which is an Apollo lunar roving vehicle simulation being developed for students. It is an interactive 3D simulation in which students plan and perform moon rover exploration traverses that are based on the actual thermal model from the Apollo Lunar Rover Vehicle (LRV) missions. The displays are designed to mimic operation of the LRV hand controller, power and navigation systems on the display console, and moon terrain. The simulation is a balancing act between educator's goals to teach math and science and students' desire to have fun. The effort tries to bring technical space subjects to life for people who have no interest in math and science. It is consistent with the President's Space Exploration Commission's view that video and simulation games have enormous potential to educate and inspire students about space.



Scene from the high resolution rendering of LUROVA (Apollo XV Lunar Roving Vehicle deployment) (Photo courtesy of Bruce Damer)

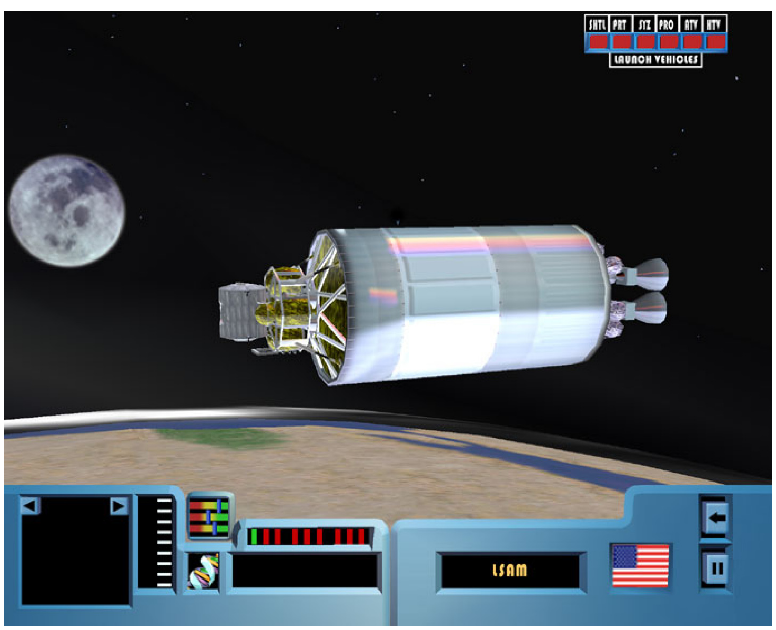
In the LUROVA simulation, the adventurer plans, prepares, and performs science traverses to meet mission goals. The post-traverse score is based on the ability to meet driving goals and match power and thermal predictions. The adventure begins with the selection of a Moon landing site by either the adventurer or "mission control." Planning tasks include exploration goals, Extra Vehicular Activity (EVA) time, science stops, and mobility, power and thermal predictions. The preparation phase includes unfolding LUROVA from the Lunar Module (LM) and configuring it for the traverse. The student performs the traverse using the display console, navigation system, and hand controller. Post traverse tasks include powering off, reading displays, brushing the radiators and preparing for LM ingress.

The simulation is designed to be as realistic as possible. In the future, plans are to expand on the initial "lightweight" models and integrate terrain and 1/6 gravity driving models. These enhancements would further improve the reality of the simulation.

Ron Creel at the LRV Thermal Model Control Console, early 1970s
(Photo courtesy of Bruce Damer)

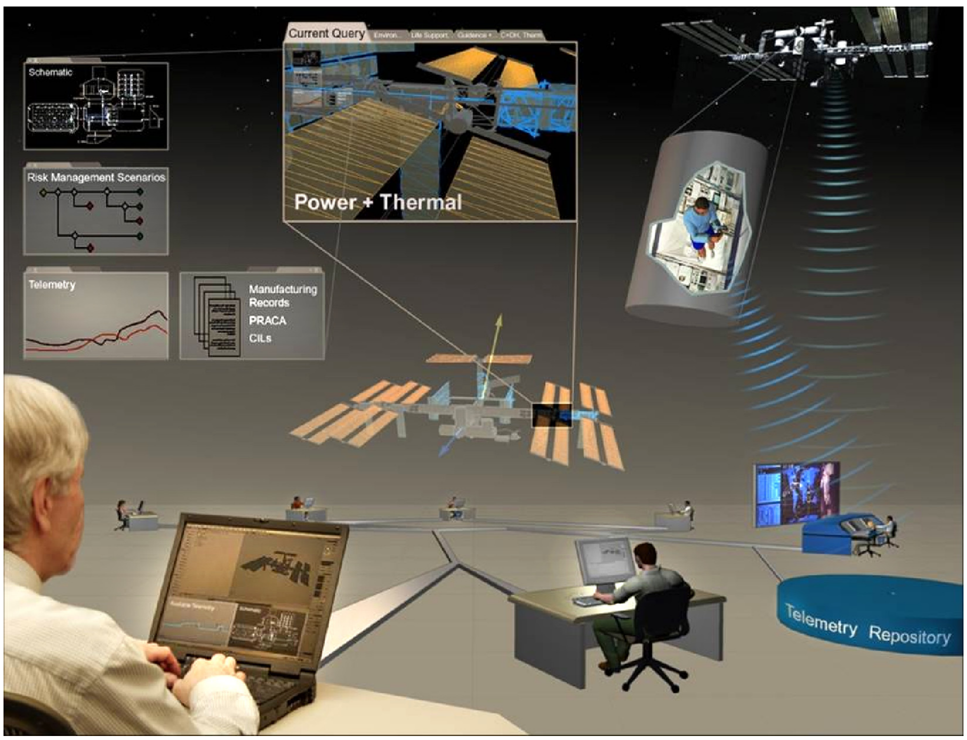
Having worked on actual Apollo missions to the moon, Ron was emphatic about his feeling that space games and simulations, if meant for learning, must be realistic, and not feature fantasy, racing, or "shoot-em up" elements.

II.5 Ongoing Work for the NASA Constellation Architecture Integration Team



Lunar sortie simulation using Vision Videogame's technology
(Photo courtesy of Bruce Damer)

Tom Cochrane of NASA Ames Exploration Technologies spoke about systems integration in virtual environments. The driving force is the need for interactive access to systems knowledge. Systems of interest like the International Space Station (ISS) are very complex and integrated. He discussed a number of simulations and tools. The SimConstellation simulation tool runs various lunar mission scenarios using the new Constellation architecture. As an example, he showed a lunar sortie mission scenario. It involves separate launches of the Ares I carrying the Crew Exploration Vehicle (CEV) and the Ares V carrying the Earth Departure Stage (EDS). After rendezvous and docking of the CEV and EDS, a Trans Lunar Injection (TLI) sends the lunar lander/CEV to the Moon. The planned lunar sortie missions would begin with four-person crews making seven-day trips to the Moon until the power supplies, rovers, and living quarters of an outpost are established. He showed the first planned sortie mission that is a fly-by rather than a landing.



SimStation (Photo courtesy of Bruce Damer)

He discussed the project SimStation, a collaborative project with Mark Shirley to realistically simulate the ISS. SimStation is a tool that is capable of understanding a complex system with tightly coupled interactions. It is a systems thinking workbench for ISS that creates a space for shared understanding and "what-if" brainstorming. SimStation is organized around an integrated data model that contains structural (how are the parts connected), functional (how do the parts work), and behavioral (conditions and failure modes) aspects. SimStation can be used to look at behavioral trade capabilities. For example, by monitoring the orbit and attitude of the ISS, it can estimate the lighting on the solar arrays to determine inputs into an energy storage model for the ISS. SimStation is an excellent tool for determining the consequences of unexpected events such as electrical faults, and reduces risk by anticipating their effects on overall system performance.

III. We All Get To Go

III.1 Exploring a Toy Galaxy

Will Wright (Photo courtesy of Bruce Damer)

Will Wright, creator of "SimCity" and "The Sims" gave the foundational talk in the **we all get to go** session entitled "Exploring a Toy Galaxy". The underlying theme of the talk was astrobiology, which succinctly stated is the study of the origin, evolution, distribution, and future of life in the universe. He discussed some of the literature on this subject, such as Peter Ward's book entitled *Rare Earth*, which contends that complex (intelligent) life in the universe is uncommon, and *Cosmic View* that presents a view of the cosmos over 40 orders of magnitude in scale.

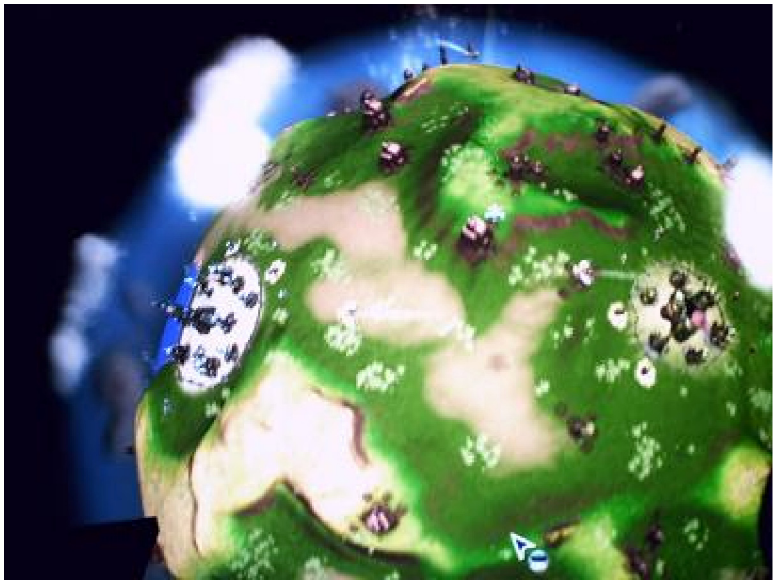
He also discussed Drake's Equation that states N is the number of civilizations in our galaxy with which communication might be possible as

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

where,
N = the number of technological civilizations in the galaxy
R^* = the rate of formation of stars suitable for the development of intelligent life
f_p = the fraction of those stars with planetary systems
n_e = the number of planets in each planetary system with an environment suitable for life
f_l = the fraction of suitable planets on which life actually appears
f_i = the fraction of life-bearing planets on which intelligent life emerges
f_c = the fraction of planets with intelligent life that develop technological civilizations
L = the lifetime of a technological civilization

The terms are conventionally grouped into the categories astronomical (R^* and f_p), biological (n_e, f_l, and f_i), and cultural (f_c and L).

He touched on the Fermi Paradox concept, which tersely stated is the conundrum that while the basic conditions for life are met in our galaxy, there is no evidence whatever for the existence of extraterrestrial civilizations. Another concept mentioned was the possibility of directed panspermia missions to other stars. For example, the Society for Life in Space (SOLIS) is dedicated to promoting life in space through directed panspermia (http://www.panspermia-society.com/).

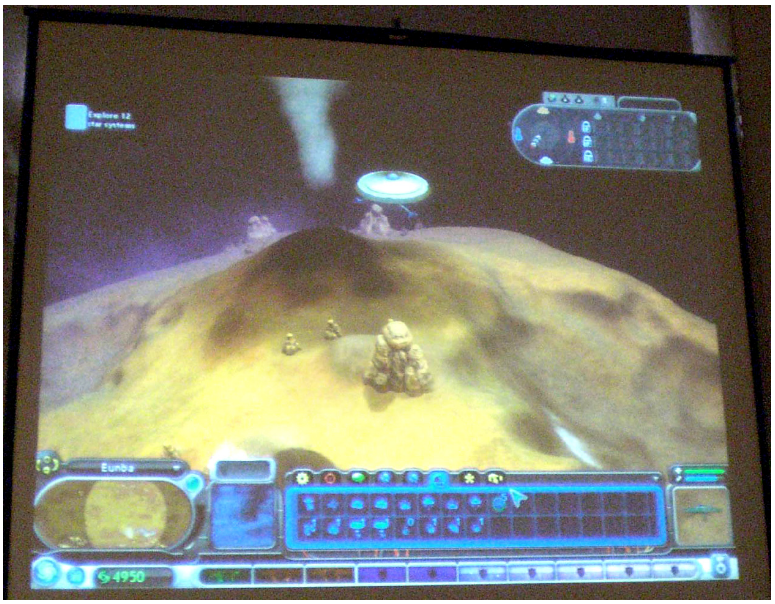


View of a planet in *Spore* (Photo courtesy of Bruce Damer)

Will Wright spoke at length about science fiction that has captured the imagination of generations. The media include movies such as "2001: A Space Odyssey," books such as the Uplift Series by David Brin, and magazines such as "Amazing Stories." This overview of past media for science fiction preceded a demonstration of *Spore*, a video game Wright designed for Maxis that was released in September 2008. *Spore* is a multi-genre, massive single-player, online metaverse video game. It allows a player to control the evolution of a species from its beginnings as a unicellular organism, through its evolution to an intelligent speaking creature, to its evolution as a spacefaring culture. The player can even tailor his or her own planet.

Creature editor in *Spore* (Photo courtesy of Bruce Damer)

The game has significant educational potential and it encourages creative and imaginative thinking. The video game is impressive in its scope and use of open-ended gameplay and procedural generation (to create content when needed). However, games like *Spore* require very large financial investment. The *Spore* user interface has required more than 10 rewrites of the system. Total investment in the game is in excess of 30 million dollars.



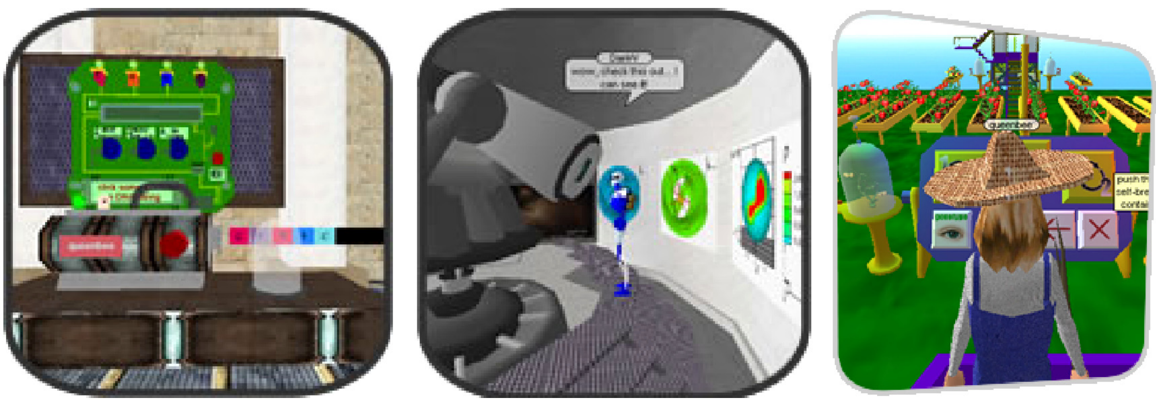
Screen display of Will's live preview of *Spore*
(Photo courtesy of Bruce Damer)

During discussions subsequent to his talk, Will Wright agreed that educational games require the same investment as commercial games. Game worlds should be analogs of targeted content, knowledge, and skills. Gameplay should be designed to position learners to discover targeted knowledge by making, testing, and refining hypotheses about the game system. Game knowledge could then be embodied knowledge, and, by design, it would be a viable analog of the targeted learning domain. Game goals would be designed so that gameplay positions players to construct that viable knowledge. This characterization of game design (game worlds as analogs of targeted concepts that scaffold player's emergent mental models through discovery) may seem obvious, but it is not necessarily realized or followed by game designers, because game design is a young field. The field of educational game design is even younger.

Contemporary initiatives support a vision of educational game repositories. The repositories could manage and assess learner progress through game-based learning objectives. These games would be expensive to produce. The vision is for national (or global) investment by all sectors: education, business, governments, science, organizations, and industry. Participation by the game industry would leverage, for educational purposes, the great expertise and resources the industry has already accomplished.

III.2 The SciFair Model: Supporting Teams of Kids Creating Virtual Worlds

Margaret Corbit, Manager, Research Outreach, Cornell Theory Center and Director, SciCentr.org, discussed the SciFair Model that is deployed in SciCentr, a novel online science museum that exists only in Cyberspace (http://www.scicentr.org/). It is based on a multiuser chat world technology that appeals to teens and young adults. SciCentr leverages the multi-user game environment to present educational science content and simulations in a safe social setting. The first stage of the SciFair sequence is to introduce the student to the medium, for example, how to navigate in the virtual world, and how to use the available building materials to create their own spaces within the virtual world. This helps the student to master the technology and to build social interactions within the virtual community. SciCentr is efficient (less than 6 Megabyte (MB) per client) and is a secure extranet with access to the Cornell University private universe and over 130 other worlds. Other aspects include chat technologies, game interaction, and multimedia integration. Involvement in SciFair helps middle school students develop FITness (Fluency in Technology and computer literacy).



Scenes from SciCentr (Photo courtesy of Bruce Damer)

In the second stage of the SciFair model, the student is introduced to the content, which is a selection of specific research areas that can be updated on a continual basis. This is followed by team formation and identification of the roles that need to be filled in the team-based development of virtual game worlds (for example, landscape architect, game interaction designer, web designer, etc.). The team negotiates over the specific scientific theme of the project, and then the team with coaches and mentors develop a plan for the final project. Finally, the student teams and mentors present their work to each other and to members of the community in a SciFair showcase.

SciFair Showcase (Photo courtesy of Bruce Damer)

The goals of SciCentr include familiarizing the students with new concepts in technology and science topic areas, team building, and communication skills. It attempts to engage K-12 students in a multigame environment that makes learning science fun. Some of the challenges to the SciFair model are the acceptance of computer games in school, logistics (lab access, equipment, busses, stipends), capacity of the system, and sustained support.

III.3 Educational Applications and Pedagogical Underpinnings of Virtual Worlds

Daniel Laughlin, Assistant Research Scientist, Information Science and Educational Technology, Goddard Earth Sciences and Technology Center, discussed the pedagogy of virtual worlds. The latest industry estimates are that between 20 and 30 million Americans currently participate in persistent immersive synthetic environments. For example, *World of Warcraft* is estimated to have ~9.5 million players and *Second Life,* 10 million. The majority of families believe that video games can be a potential source of learning. Pedagogy, which is the art or science of being a teacher, must deal with the issue of what makes learning work. Dr. Laughlin discussed this in terms of learning theory, touching on the work on pragmatism by Charles Sanders Pierce and William James, on experiential learning by John Dewey, and the mental model theory of Phil Johnson-Laird. In practice, individuals learn by exposure to new ideas, experiences, and more intricate models. Cognitive science research supports the theory that all learning is synaptic. Given that engagement makes synaptic learning more likely and that good games are engaging, it follows that individuals learn from playing games. Immersive synthetic environments have qualities such as built in engagement, fast feedback, cognitive outsourcing, improved telepathy, and particularly easy repetition that make them excellent tools for promoting learning.

III.4 K-20 Education: Distance Learning and Collaboration Using *Second Life*

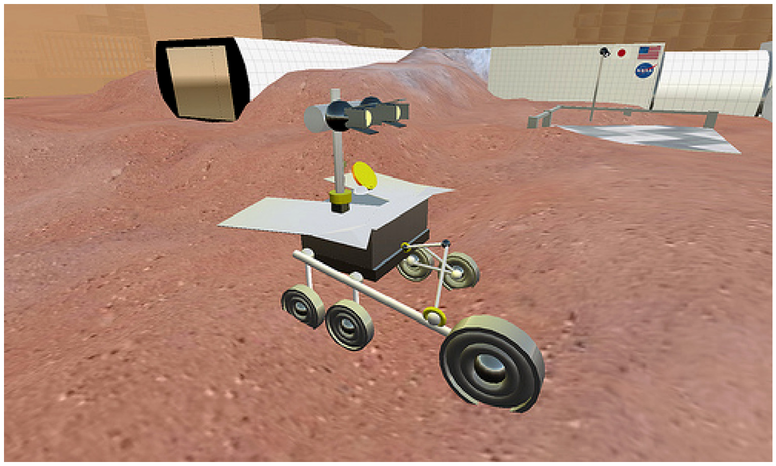
Cathy Arreguin, virtual educator and curriculum developer, San Diego State University, and Stan Trevena, Director, Information and Technology Services, Modesto City Schools and co-founder of the Pacific Rim Exchange project on the Teen Grid of *Second Life*, presented a paper entitled "K-20 Education: Distance Learning and Collaboration Using *Second Life*." They described the Pacific Rim Exchange project, which was a foreign exchange program carried out in *Second Life* between Modesto city schools and Kyoto Gakuen high school in Japan. The major goal was to provide a persistent virtual space for communication, collaboration, and cultural exchange between the students of Modesto and Kyoto. Initially students used a chat translator to communicate, but full spatial voice support was later added. Video conferencing was used to supplement communications between the students.

The initial land mass was three islands on the Teen Grid of *Second Life*. Later the shared space was configured into four shared islands and the students and teachers built everything on the islands. Students were free to claim personal dorm rooms on the island and decorate them appropriately. This provided a venue for the students to display their creations and information about themselves and their avatars. Bridges were built between the islands in a collaborative team project.

View of the "bridges" in PacRimX world in *Second Life*
(Photo courtesy of Stan Trevena)

Cultural exchange was facilitated through organized island events focused on the sharing of cultures (holidays, history, and traditions).

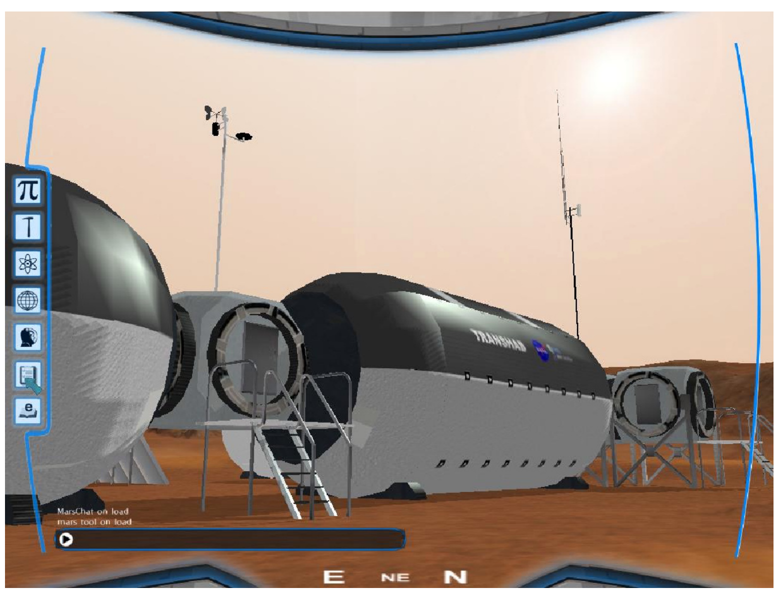
In preparation for the virtual worlds workshop, the students were asked to construct a virtual Mars colony. They were provided some web sites and research ideas. Both Japanese and American students built the Mars colony over a one-week period.



View of a Mars rover and base in *Second Life* (Photo courtesy of Stan Trevena)

The project in *Second Life* proved to be a very effective way of engaging students. Clearly, virtual worlds will play a role in the future of education. Students learn by doing and virtual worlds allow for rapid prototyping of student ideas in simulated spaces. Students engage in these environments because they are fun. This experiment provides impetus for a NASA Massively Multiplayer Online Environment (MMOE). A realistically rendered environment would engage students in learning and exploring. Interest in the sciences could be reawakened in the 'gaming generation'.

III.5 Exploring the Multiverse

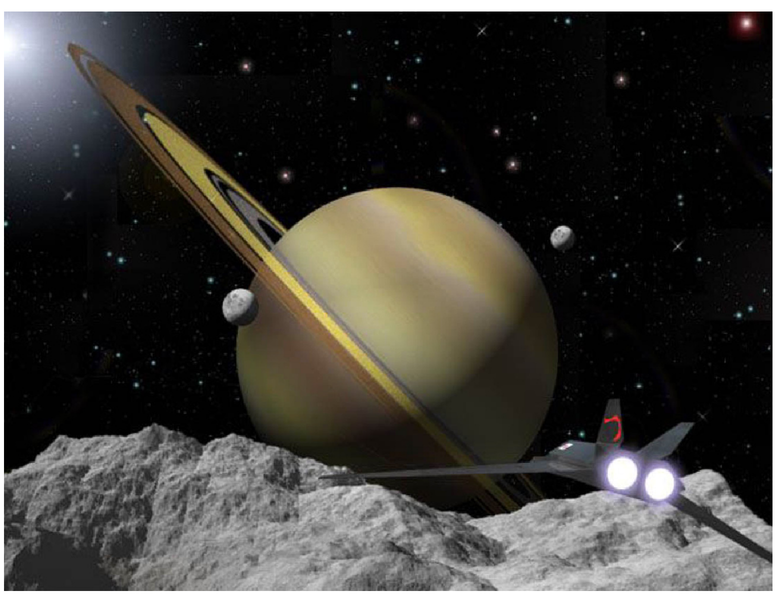


Mars base in Multiverse (Photo courtesy of Bruce Damer)

Cory Bridges, Co-founder, Executive Producer, and Marketing Director of Multiverse, discussed the Multiverse network—the leading network of online multiplayer games and 3D virtual worlds. Their goal is to create a large-scale media platform that significantly reduces the time and cost of creating virtual worlds. Virtual worlds are in a period of rapid growth. They have the characteristics of being immersive, interactive, persistent, and online. This gives them wide applicability for video games, social interaction, training and simulation, business collaboration, education, and sales and merchandising. Although there is considerable demand for virtual worlds, only a few major players, such as *World of Warcraft* and *Second Life* exist today. This is due, in part, to the cost of developing and launching them, but also due to the proprietary technology on which they are based. Currently there are limited genres, lack of synergy between worlds, and significant learning curves for new users.

The Multiverse platform is based on a free world browser, a scalable server, easy-to-use development tools, and content standards. The Multiverse network provides a common infrastructure and aggregation over a larger consumer base. The platform significantly reduces the cost and development time for both large game and social world virtual worlds. This presents a strategic opportunity for organizations developing either virtual worlds or massively multiplayer games. To date there are over 17,000 registered developers in Multiverse, and a growing number of prototype worlds. Some of the worlds in progress, such as *Lunar Quest*, were demonstrated. The Multiverse technology stack uses a scalable client/server platform that can be customized for a broad range of online worlds. Multiverse sees an impending revolution in virtual worlds analogous to the web explosion of 1995.

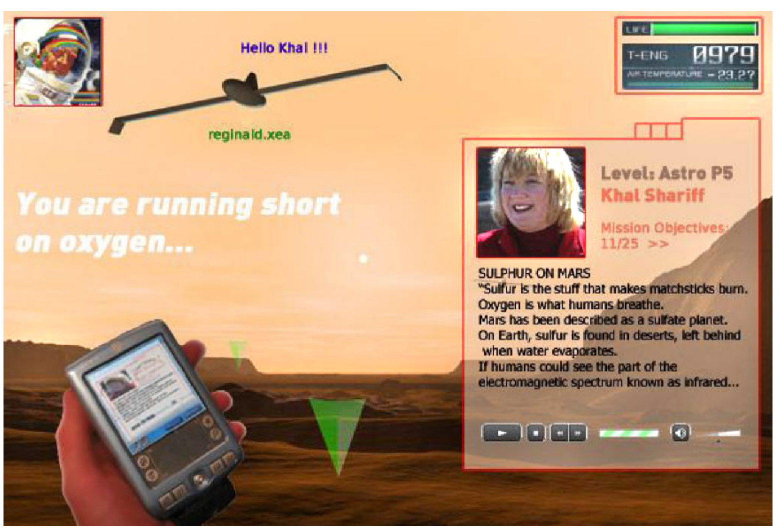
III.6 Opening the Universe



View of the work of Khal Shariff (Photo courtesy of Bruce Damer)

Khal Shariff, of the Virtual Reality Center in Winnipeg, Canada, and CEO of Project Whitecard Inc., presented a paper entitled “Opening the Universe: Virtual Space Exploration Begins!” His talk was focused on how to build a Massively Multiplayer Online (MMO) game to engage the community in the participatory exploration of space. Ideal attributes of the game are that it is engaging, educational, related to space, and set in the near future (20-30 years out). *Second Life* has some of the characteristics needed for a platform, such as accessibility and no cost. Since *Second Life* is a community, it has inherent in it the tools that allow every user to contribute to its substance and experience. For example, meetings in Second Life can be fun and useful. Drawbacks include its lack of rigorous physics and the perception that it is not a game. We need something more than *Second Life* to bring science to life through an MMO game. Physics and science mean more within a good physics engine. The best games provide rich experiences through storytelling and plots that weave and change. This puts the onus on game developers to create a narrative. The game has to have a balance between being educational and entertaining. However, in a serious game of space science, the environment must contain realistic data, and it must be updateable as better data becomes available (e.g., higher resolution).

Some of the characteristics of a good game are that it has an exciting narrative, uses interesting characters, creates mission goals, and rewards success. Both teachers and students need to be enriched by the experience. There is a tradeoff in game design between having fast action “racing games” and reality mode and learning games. Ideally a game would feature both of these aspects and thereby provide both learning and fun gameplay. One approach to enhance learning is to include Artificial Intelligent Mentors (AIMs) or real people who have advanced skills and knowledge as part of the game. In summary, a good MMO game should use real science, be entertaining, have a narrative, have learning objectives, have some means of assessment, be multi-user, and use either AIMs or real scientists as facilitators.



Example of mobile simulation/game experience
(Photo courtesy of Bruce Damer)

NASA can help lead the way with new paradigms in the game mechanics and provide realistic data, e.g., high-resolution images of the surface of Mars. The data should reside in a common database and be accessable through a web 2.0 interface to make it easy for teachers to enter data and link learning modules. A commercial partner would help ensure success by providing the latest technology for combining Web 2.0, virtual reality, and game technology. It is possible to make games both entertaining and educational, as evidenced by the recently released game *Spore™*, which combines fun with learning about evolution and astrobiology.

III.7 New Methods in Simulation Applications for Education: A Real World Example, "The Lunar Racing Championship"

Mary Duda, CEO/President of VirtuePlay, Inc. first discussed the VirtuePlay *Lunar Explorer*, which is a realistic interactive visual representation of the Moon using the data from the 1994 Clementine mission. It uses real-time 3D graphics techniques to provide an immersive virtual environment for the user to explore the Moon at a distance, from orbit, or walking on the lunar surface.

Vehicle from the VirtuePlay Lunar Racing Championship
(Photo courtesy of Bruce Damer)

The main focus of her presentation was on the new *Lunar Racing Championship* (LRC) MMO game created by Virtue Arts Inc. A key point is to use gaming technology as a platform for education, or, more specifically, to use VirtuePlay's high-level game engine and real science merged with fantasy to create an immersive learning system. The game is based on proprietary software for building simulation applications. This includes both Rapid Application Development (RADE) software, and a Rapid Application Scripting Language (RASCL). The LRC game has the goal of creating an exciting experience that engages the player as a lunar racer. Through immersion racing on the Moon, the user gets some of the experience of being there. The software allows players to create their own games and to build their own lunar rover. The game attempts to simulate the actual physics of the Moon (e.g., reduced 1/6 gravity) and to use accurate terrain data. The LRCMMO has

View from cockpit of one of the LRC racing vehicles (Photo courtesy of Bruce Damer)

been well received at a number of promotion events. PC and Mac video game versions are available, and an Xbox 360 version should be coming out later in June 2009 as a download on Steam (http://store.steampowered.com/).

III.8 From 2-D to 3-D Web: The Science Center in *Second Life*

Rob Rothfarb, Director of Web Development at the Exploratorium and co-founder of ‘Splo, discussed the informal science education exhibits and programs that are available at San Francisco’s Exploratorium. The Exploratorium’s key functions are to promote science education through pub-

View of the 2006 solar eclipse in *Second Life* hosted by the Exploratorium (Photo courtesy of Bruce Damer) lic exhibition and research and development into new media, learning technologies, and informal learning. They have over 50 live web casts per year. One of the more notable recent web casts was of the 2006 solar eclipse from Side, Turkey. However, in addition to showing this at the museum and on the web, they presented a live web cast of the solar eclipse coverage from Turkey in three virtual *Second Life* amphitheaters. People from all around the world, represented by their avatars, could share the experience by chatting with each other and with the staff at the Exploratorium. Social interaction with others through instant messaging, gestures, and chats is one of the most important features of *Second Life*. Another unique aspect of *Second Life* is the ability to experience the impossible in the real world, such as altering gravity to allow you (your avatar) to fly or teleport to anywhere in *Second Life*.

'Splo world in Second Life (Photo courtesy of Bruce Damer)

He also discussed *Second Life*'s interactive museum of science, perception, and art called 'Splo, which has more than 100 Exploratorium-inspired exhibits. Exhibits such as the Impossible Triangle, Distorted Room, and Pi Day are very interesting and creative. The ability to fly affords many interesting perspectives. He also discussed the Transit of Mercury webcast and orbit exhibit and the Meteor Impact Simulation on Mars exhibit. The meteor impact simulation shows an asteroid hitting Mars at 1/10th speed and creating a 50-meter diameter crater. It is much safer to observe up close virtually with your avatar than in the real world. The Exploratorium is committed to continuing to experiment and expand the social, contextual, and educational possibilities of *Second Life* through future live events.

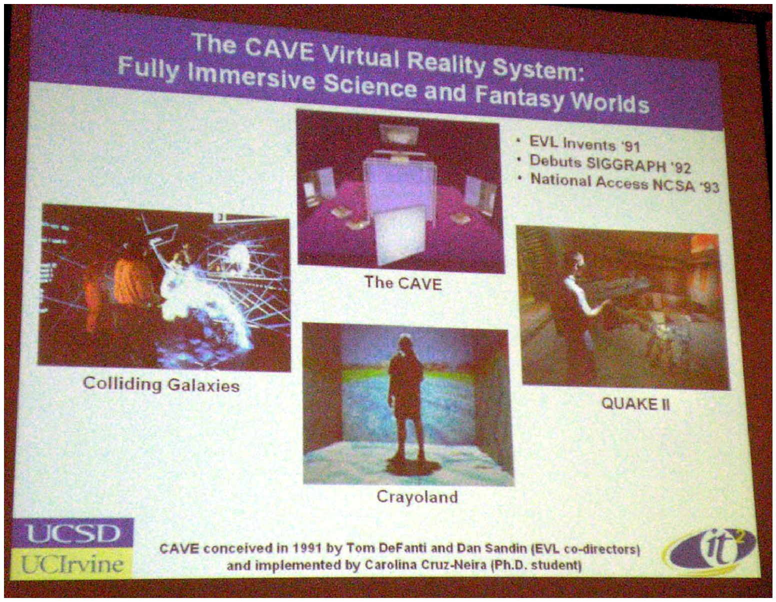
IV. Become the Data

IV.1 Remote Telepresence for Exploring Virtual Worlds

Larry Smarr, Founding Director of the California Institute for Telecommunications and Information Technology, and Harry E. Gruber, professor in the Jacobs School's Department of Computer Science and Engineering at UCSD, gave the foundational talk on **become the data** session entitled "Remote Telepresence for Exploring Virtual Worlds." Telepresence refers to a set of technologies that allow a person to feel that they are present. By using high-speed, fiber-optic links between computers in two different geographical locations, distance between individuals who wish to interact can effectively be eliminated. He showed how communication technology had changed from the late 1980's, where the network connecting the six National Science Foundation (NSF) supercomputers (NSFnet) ran at 56 kilobytes per second, to today's optical networks that run at greater than 100 gigabytes per second (Gbps).

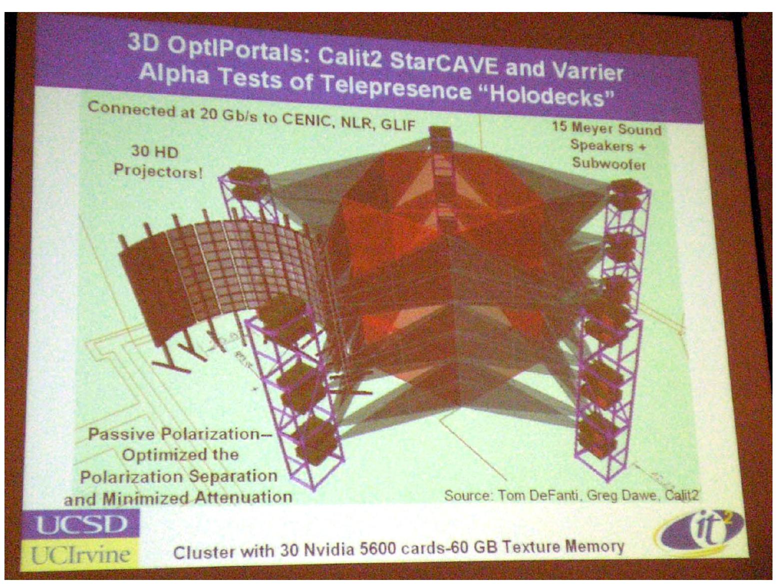
Larry Smarr (right) with early mega-pixel display (Photo courtesy of Bruce Damer)

He highlighted some of the collaborative work going on at the California Institute for Telecommunications and Information Technology (Calit2). Two new buildings being built at Calit2 will house over 1000 researchers linked between dedicated optical networks. Facilities for studying nanotechnology, photonics virtual reality, digital cinema, high-definition television, etc. will be colocated. He discussed the development of a global LambdaGrid cyberinfrastructure that connects university research centers at 10 Gbps. With this new architecture, it is possible to access scientific data anywhere in the world over optical networks as if the data were stored on a local hard disk. This enables persistent high-performance collaboration on a global scale that in turn permits a new level of scientific discovery. He showed a number of examples of global collaboration from kids building virtual cities, to using distributed virtual reality for global-scale collaborative prototyping, to analysis of ecosystem dynamics datasets. The high-band width optical networks enable trans-Pacific super high-definition telepresence meetings using digital cinema 4k streams (4000x2000 pixels). For comparison, the resolution is 100 times that of YouTube.



CAVE environments through the years (Photo courtesy of Bruce Damer)

Larry Smarr next discussed the OptIPuter project, whose goal is to create high-resolution portals over dedicated optical channels to enable the global sharing of large data sets. The OptIPuter (so named for its use of Optical networking, Internet Protocol, and computer storage, processing and visualization technologies) is an envisioned infrastructure that will tightly couple computational resources over parallel optical networks using the IP communication mechanism. The OptIPuter exploits a new world in which the central architectural element is optical networking, not computers. The goal of this new architecture is to enable scientists who are generating terabytes and petabytes of data to interactively visualize, analyze, and correlate their data from multiple storage sites connected to optical networks.



Vision for the full OptIPortal (Photo courtesy of Bruce Damer)

The OptIPuter enables telepresence combined with remote interactive analysis. He showed, for example, a remote interactive high-definition video of deep-sea hydrothermal vents. OptIPortals have proven to be very useful and are being adopted globally.

Use of high resolution multidisplays for telepresence collaboration (Photo courtesy of Bruce Damer)

Another topic that he touched upon was VR systems. Specifically he discussed the CAVE at Calit2, which is a surround-screen, surround-sound, projection-based VR system. The illusion of immersion is achieved by projecting 3D computer graphics onto display screens that completely surround the viewer. It is coupled with a head tracking system to produce the correct stereo perspective. The CAVE is designed to be a useful tool for visualization. Used in conjunction with high-resolution data sets, it achieves the goal of telepresence.

IV.2 Why Open Protocols Matter

Christa Lopes, Professor of Informatics, Donald Bren School of Information and Computer Sciences, UC Irvine, spoke about the advantages of open protocols. She talked about two case studies both presented within *Second Life*. First, she discussed Metaverse Ink's SLBrowser search engine, now known as Metaverse Ink Search. This is the first and only independent search engine for virtual worlds, searching over two million products in tens of thousands of virtual places. It has the advantages of being free and configurable. A more detailed discussion and comparison with the Linden

Labs search engine can be found at http://www.metaverseink.com/. Secondly, in *Second Life* she presented a demonstration of Unimodal's SkyTran system—a very high-capacity and high-speed personal rapid transport network. The SkyTran system operates with individual, two-passenger vehicles, which are propelled by a maglev system from overhead guide ways. A large number of exit portals make this system highly flexible. Although the physics (e.g., of the maglev system) are not accurate in *Second Life*, the simulation still provides unique insights, largely from the ability to view the system from unique vantage points that can be reached by the user's avatar.

Simulation of a rapid transit system in *Second Life*
(Photo courtesy of Bruce Damer)

In the second part of her presentation, she spoke about the advantages of Libsecondlife and Open-Sim. Libsecondlife is a software library that can be used in a third party application to communicate with the servers that control the virtual world of *Second Life*. For example, it can download the shape and appearance of a building or avatar, and it can upload new virtual objects. It is based on a well-architected Application Programming Interface (API) and is open source. OpenSimulator is a 3D Application Server that can be used to create a 3D virtual world. It is open source and commercially friendly to embed in products. Although it does not have the stability of the much older Linden Lab simulators, it has many useful features such as an extensive ability to customize avatars and the ability to create content in real time using in-world building tools.

IV.3 Life After the Orphidnet

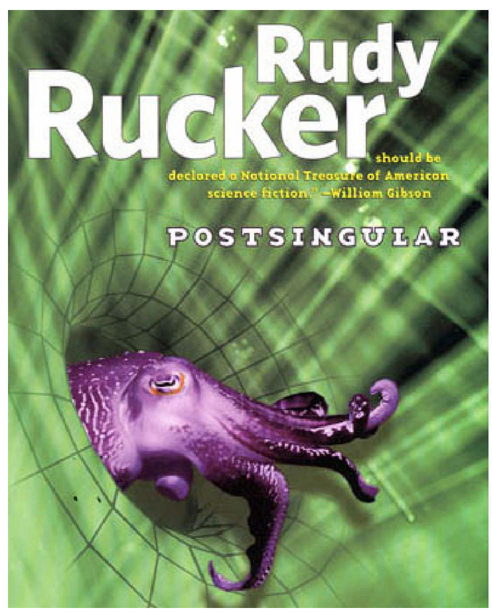
Rudy Rucker, author, scientist, artist and professor in the Department of Mathematics and Computer Science at San Jose State University, gave a paper entitled “Life after the Orphidnet,” a concept discussed in his novel *Postsingular*. In the novel the planet becomes carpeted with a Global Position System (GPS) grid based on self-reproducing nanomachines called *orphids*. The concept is best described by the following two quotations from the novel.

“Orphids self-reproduce using nothing but dust floating in the air. They’re not destructive. Orphids are territorial; they keep a certain distance from each other. They’ll cover Earth’s surface, yes, but only down to one or two orphids per square millimeter. They’re like little surveyors; they make meshes on things.”

“She let herself see the dots on her fingers, dots on her palms, dots all over her skin. The glowing vertices were connected by faint lines with the lines forming triangles. A fine mesh of small triangles covered her knuckles; a coarser mesh spanned the back of her hand. The computational orphidnet was going to have real-time, articulated models of everything and everyone.”

Discussion focused on the implications for privacy if this information were readily available. Rudy advised that we might be moving to a post-privacy world. Larry Smarr, who had presented the session’s foundational talk, agreed with Rudi, stating that privacy has been a 200-year anomaly due to the growth of cities. At this juncture, all stakeholders should pause to consider how virtual world technologies enable humans to engineer the future. What metaphors and parameters would be most conducive to positive and optimal experience? Rather than passively accept what evolves, we should apply our greatest intelligence to this philosophical, ethical, and engineering opportunity.

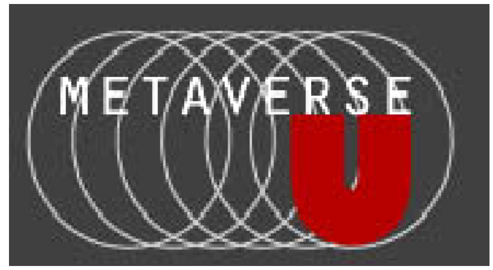
Rudy Rucker (Photo courtesy of Bruce Damer)



Rudy Rucker’s newest novel *Postsingular* which features the Orphidnet concept (Photo courtesy of Bruce Damer)

IV.4 How Virtual Worlds May Augment Collaboration

Henrik Bennetsen, Research Director at the Stanford Humanities Lab, spoke about how virtual worlds may augment collaboration. Virtual worlds began with the early web, and have matured into effective tools for collaboration. For example, one of the significant uses of *Second Life* is for meetings and facilitating collaboration. Communication tools such as text chat and voice work well, and can be superior to video conferencing or web-enabled teleconferencing. Another example is *Project Wonderland*, a virtual world that Sun Microsystems has created to facilitate interactions among its employees.



Metaverse U event hosted by Bennetsen at Stanford (Photo courtesy of Bruce Damer)

He discussed the black box fallacy, which is the idea that all devices would converge into one central device that did everything for you. The opposite appears to be the case—a proliferation of black boxes—in part driven by the changing context in which we consume information. He also talked about crowdsourcing, the act of taking a task traditionally performed by an employee and outsourcing it to an undefined, generally large group of people. For example, the public may be invited to develop a new technology or carry out a design task. The term has become popular as shorthand for the trend of leveraging the mass collaboration enabled by Web 2.0 technologies to achieve business goals.

Henrik Bennetsen (Photo courtesy of Bruce Damer)

He next discussed the concept of democratizing innovation, which is the idea that innovations by lead users precede commercialization. In other words, initially only a few users perceive the need and only a few prototypes are available, but as more users see a need for a product, commercial versions of the product become available. This is currently the situation with in-world collaboration tools. Finally, he discussed the International Spaceflight Museum in *Second Life*, which hosts exhibits and events about real-world spacecraft, rockets, and space travel. The museum is located on the island Sims Spaceport Alpha and Spaceport Bravo.

IV.5 Living Beyond Ourselves: How the Next Crewed Mission to the Moon Could Transform the Way Humanity Experiences Life

George Whitesides, Executive Director, National Space Society, discussed how new technologies are needed to reach post-Apollo generations that are empowered and in control of their media experiences. He discussed the work of the National Space Society (NSS), which is a non-profit organization dedicated to the promotion of space exploration and settlement. The mission of the NSS is to promote social, economic, technological, and political change to expand civilization beyond Earth and to settle space. He described some of the educational programs within NSS, but focused on their recent experiment in *Second Life*. Inspired in part by NASA CoLab, the society bought an island in *Second Life* and turned it over to their members for development of lunar tools, architecture, communication, transport, mining equipment, etc. The experiment showed the importance of having a medium in which young people can interact.

He advised NASA to use these new virtual technologies to engage the public and for education. He felt that NASA should begin planning the infrastructure for broadband multidimensional data to make the exploration of the Moon a milestone in virtual presence. This includes flexible communication architectures, large bandwidth, and plans to embed many dimensions and senses. Future technologies will enable immersive experiences in digital worlds, such as 3D video with multi-sensory and telemetric augmentation. During the next lunar landing, the public should be able to participate in the descent through an interactive high-definition video link.

IV.6 Democratizing the Universe

Ed Lantz, Founder of The Harmony Channel, operates Visual Bandwidth Inc. and is Chief Technology Officer for Vortex Immersion. He discussed how to create and deliver a scientifically accurate virtual universe to the masses. Since the universe is too large to experience firsthand, it must be experienced virtually though data sets and models. Scientists have a responsibility to make scientific data available so the public can understand the knowable universe, and society can develop a shared cosmology.

Full-dome projection technology as presented by Ed Lantz (Photo courtesy of Bruce Damer)

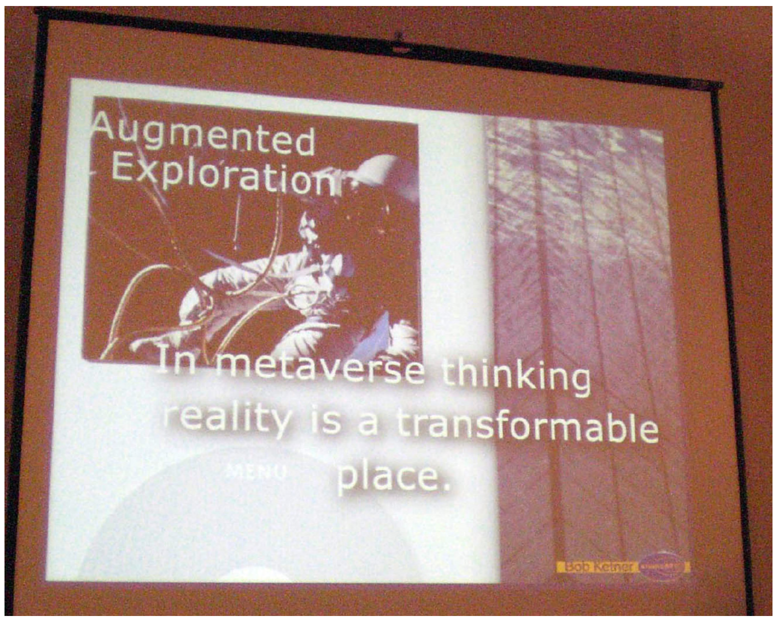
Mr. Lantz discussed levels of virtual reality that span the gamut from the real environment, to augmented reality, to an entirely virtual environment (VE). He defined a VE to be a 3D environment within which one can navigate and interact using VR interfaces that immerse the senses sufficiently to replace perception of the ordinary world with a sense of presence in an intentionally manipulated virtual, artificial, or enhanced environment. These technologies include augmented reality and projected information overlays, large-format displays and wrap around screens, and computer games and interactive spaces. Spatial immersive displays span the gamut from the personal small scale (CAVEs and domes) to multi-person medium scale (reality centers and mega-walls), to large groups (fulldome theaters and wrap-around screens). Spatial augmented reality (the more general class of VR inclusive of spatial immersive displays) projects virtual features onto real-world environments and architecture. He believes that spatially augmented reality technologies are where much of the action will be in the near future, as projection technologies and image-based user interfaces mature including multitouch tables and gesture interactives. Essentially, he says, spatial augmented reality can take virtual worlds and social networks—now popularly accessed via a computer screen, keyboard, and mouse—out of the box and project them around us, allowing us to interact directly with data using natural gestures without special glasses, gloves, or controllers.

As an example of what is coming in the world of entertainment technology, Mr. Lantz introduced the Vortex VR Nightclub concept. It features a domed screen over the main dance floor, an Immersive Jockey, Photonic Go-Go booths, digital theming, and gesture-based avatars (see http://www.vortex-immersion.com/). He showed a sampling of the 344 fulldome digital theaters (http://en.wikipedia.org/wiki/Fulldome) that exist worldwide, primarily in universities, school districts, science centers and museums. The number is rapidly increasing (now 481 theaters—see http://www.lochnessproductions.com/lfco/lfco.html) and has recently surpassed the total number of large-format film theaters including Image MAXimum (IMAX) theaters. Most of fulldome theaters feature realtime interactivity allowing navigation through extensive astrophysical datasets, such as the American Museum of Natural History's *Digital Universe Atlas*, now used by three major fulldome vendors (http://www.haydenplanetarium.org/universe/). He showed some examples of productions that had been developed for fulldome theaters, including Gaia journeys that are focused on gaining a more integral understanding of Earth and offer a blend of science and art. Specifically, he discussed Bella Gaia, which is a narrative SciArt experience that offers a tour of the world from the perspective of the ISS. He also discussed research to create a network of domes through the non-profit CineGrid initiative (www.cinegrid.com) to build an interdisciplinary community focused on developing collaborative tools to enable the production, use, and exchange of very-high-quality digital media over photonic networks.

View of Earth and the ISS on the Hayden Planetarium dome
(Photo courtesy of Bruce Damer)

He discussed a proposed project called *Model of the Known Universe* that would create a DomeGrid allowing access to curated scientific datasets and simulations of both macroscopic, microscopic, and quantum phenomena, and access to remote immersive cameras (including one on the ISS), essentially turning the domes into regional group immersion portals. Such a project would likely be multinational, multi-institutional, and multidisciplinary in nature, requiring substantial funding from a variety of sources. With a well-designed set of intellectual property agreements, these datasets could be disseminated via the web, fulldome portals, and even to content creators and filmmakers for an appropriate, pre-negotiated license fee. Such a program would assure that the fruits of science are truly shared with the public, thereby "Democratizing the Universe."

IV.7 Shrinking Space: Designs for Augmented Exploration



Bob Ketner's presentation on Augmented Exploration
(Photo courtesy of Bruce Damer)

Bob Ketner, Studio SFO and Virtual World Sig, spoke on the subject of "Shrinking Space: Designs of Augmented Exploration." He noted that the basis of exploration is not the place itself, but the data retrieved from the place. Just as the optical telescope augments the eye, radio telescopes augment perception of the entire radio frequency spectrum, robots extend presence to hostile remote places, and augmented exploration recreates a place in a "you are there" sense. Virtual worlds will function as a microscope, not a telescope.

"The metaverse" is not a simulation. In metaverse thinking, "real" places are actually artifacts. Real places are akin to museums, records of efforts passed, and are databases. He discussed Jean Baudrillard's "third order of simulacra" as a way to understand this. If we expect to create media experience that encompasses **we all get to go**, then the virtual presence of the viewer would be expected to contain possibly even more data than the actual astronaut would be able to access in the moment. This digitally created landscape may be modifiable by the viewer. On entering such an environment, the space between past and present is lessened in that the viewer can instantly review these states. Due to this ability, the potential for confusion increases, as the data may become a substrate for fiction or unscientific realities. In other words, in this environment in which digitally created realities become the only realities that matter, the interpretation of any given event becomes infinitely variable and volatile. There will be a constant struggle to define the interpretation of any particular finding or scientific effort.

Working to create virtual worlds as a tangible media experience includes the following:

1. **Give them something to do:** Virtual worlds and games function best when there are tangible goals to achieve within the user experience.

2. **Quest = mission:** Virtual worlds and games present goals as "quests" which contain rewards on their completion.

3. **Guild = team or school:** Virtual worlds and games function on sophisticated, team-based rules and roles. These can be very effective in directing digital work.

4. **"Class" = specialized role and abilities.** Virtual worlds enable the creation of an identity based on specialized knowledge, and this is used to partition work within the mission. Allowing users to choose their specialty generally results in either increased performance or accelerated learning about the skill. In creating virtual world experiences, consider that these are accepted standards in the medium.

We live inside an "attention economy" in which groups will form inside what can be defined as actual "virtual worlds" or "realities." This exists now in the form of cultural groups and sub-groups. However, the content of these realities is becoming instantly visible and tangible with the advent of virtual worlds. In this new augmented landscape "the street name will no longer be the same for two persons," because groups accessing various data layers will have different meanings and names applied to even physical places. This is the crucial importance of "virtual worlds" in the long term.

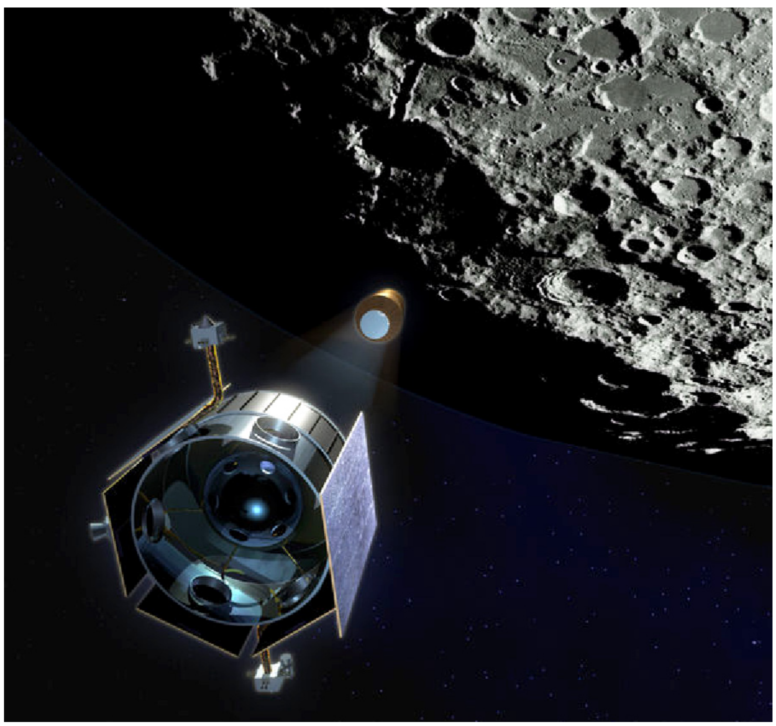
"The Metaverse is not a simulation." "The Metaverse is not a replication." "The Metaverse is not a representation of anything." These are realities that stand on their own as they are experienced while they simultaneously "allow existing realities to remain unchanged." This means that there is no cultural imperative to adopt any of these realities—they may co-exist without ever disrupting existing realities. In other words, **we all get to go** but no one has to go.

Some important factors in virtual worlds for the future include: mobile, location based services, augmented reality, smaller and lighter interfaces, surfaces as screens, and the "information in places." Virtual worlds are enabling a preview of the augmented reality to come. As such, their study is of crucial importance.

V. Breakout Sessions

In the afternoon, the workshop participants broke into three groups to discuss specific questions in more detail. The first group, chaired by Mark Shirley, looked at how virtual world environments could support near-term missions like LCROSS. The second group, chaired by Margaret Corbit, looked at what NASA could do to create a viable community developing virtual world technologies for space. The third group, chaired by George Whitesides, brainstormed how virtual worlds will be used in the exploration of space in 2020. The key results of these three breakout groups are discussed in this section.

V.1 How Could We Best Use Virtual Worlds to Support LCROSS and Other Near-Term Missions?



LCROSS mission: view of impactor deployment
(Photo courtesy of Bruce Damer)

NASA Ames Research Center's working partnership with Google has provided a wealth of NASA data to Google's Earth mapping efforts, and high fidelity Google models of the Moon and Mars are not far behind. NASA mission data and vehicle models can enrich virtual worlds and web environments in new ways just now being explored. This data also can be used to provide tools for mission planners (such as landing site selection and surface operations) as well as environments for public outreach and education. How can NASA's near-term missions (such as LCROSS) work in partnership with virtual world developers to support the full life-cycle of a mission from conceptualization to vehicle engineering, launch, mission operations, and access for the public?

Ed Lantz suggested the possibility of an immersive (fisheye or multi-head) camera on the ISS being used to engage the public in space and earth science. The ultra-wide field-of-view from such a camera mounted outside the ISS would include a view of the exterior of the ISS (including an occasional glimpse of astronauts through the windows or on spacewalks) against the backdrop of the Earth. This image would be distributed to fulldome theaters for use by real-time navigators. It also could be accessed by the public using an immersive web browser interface (see www.immersivemedia.com) that allows the public to operate a virtual pan-tilt-zoom camera that controls a virtual (planar) camera view within the near-spherical field-of-view available from the immersive camera.

V.2 How Can NASA Create a Viable Community to Develop Virtual World Technologies for Space?

How can NASA facilitate the development of virtual worlds to further the objectives of space exploration? This requires a viable community consisting of NASA staff and affiliates, both not-for-profit and for profit entities, museums, and educational institutions. The mechanism for this support could come through grants, cooperative agreements, or through contests and challenges. Should there be an internal effort at NASA, or should this effort be outsourced to small businesses or large-scale contractors that have on-going relationships with NASA? The challenge of using small businesses is that the work is not steady and there is always a threat of cancellation because of changing directions within NASA. One mechanism that has promise is to use Small Business Innovation Research (SBIR) grants. Another approach would be for NASA to issue a Request for Proposals (RFPs) on this subject, if there was a line item in the NASA budget that supported this research. Other approaches include using Space Act agreements or Memoranda of Understanding (MOUs) as a mechanism for funding or sub-contracting with companies that have the expertise in these technologies.

The group felt that NASA should be fostering a community of potential contractors/small business developers and research/education content developers. NASA might consider developing a content/producer relationship with virtual world developers. For example, NASA could provide "Starter Kits" aimed at developers in order to focus the creation of virtual world projects and provide workable units with which to create in their various platforms. A Starter Kit might contain vehicle models, terrain maps, photos, data, and mission timelines for specific missions. Each group would then work within its own capacity to build something from the seed materials or focused topic. If unable to use the raw data in a compatible format, teams could develop within their own community and capacity to address the topic and use sources that are accessible to their technology. The model is similar to a Software Developer's Kit (SDK) commonly provided for modifiable programs. Google, for example, released a SDK that served as a starting point for a developer contest with monetary rewards. This approach may identify firms and institutions that will develop long-term relationships with NASA.

A significant question is who should lead the effort to develop this content producer relationship. Possible approaches include making CoLab the central contact for the development of virtual world technologies, because of their focus on virtual worlds. Another approach is to form a virtual worlds advisory group within NASA, or an outside group to manage the development of virtual world technologies for NASA (for example, Space Telescope Science Institute or Universities Space Research Association). The advisory group could plant the seed, and define and provide "data/resource" starter kits as part of this effort to encourage further development. The advisory group could help coordinate efforts between NASA centers and serve as a focal point for coordinating the development of virtual world technologies.

V.3 2020 Vision: How Will Virtual Worlds be Used in the Exploration of Space in the Year 2020?

With multiple nations likely to be aiming to return human beings to the lunar surface by 2020, and a large number of new robotic scientific missions in the works, how will the intersection of space and virtual environments look in the year 2020? Will astronauts wear advanced augmented reality displays so that anyone back on Earth can be "virtually present" on board their spacecraft? Will robotic and human piloted vehicles traverse and dig in lunar and planetary surfaces based on real-time terrain meshes? Will humanity build its first lunar base using advanced tele-robotics, sparing cost and reducing risk to human crews? Will spacecraft be infused with complex adaptive software systems to allow them to continuously monitor vehicle health and repair themselves, allowing human crews to travel much farther than present? Will the public on Earth experience and navigate vehicles in space environments and planetary surfaces with high fidelity immersive virtual environments and **all get to go**?

The year 2020 is only 12 years into the future, but some technologies (for example, computation power, memory, and communication bandwidth that impact virtual world technologies) are increasing exponentially. On the other hand, NASA hardware and resources for space exploration are expanding much slower. By 2020, NASA should be close to having the Constellation architecture nearly complete (e.g., Ares I for launching crew and Ares V for launching cargo to the Moon). One would hope that virtual world and immersive technologies would be sufficiently advanced by 2020 to make the second phase of the exploration of the Moon a shared experience here on Earth (**we all get to go**). In doing so, however, we must deal with privacy issues of the astronauts and National Security issues. In addition, virtual world technologies will enable realistic simulations of lunar missions that have the potential to significantly impact both the lunar architecture and operations.

The group developed the idea that 2020 begins today, by making participatory experiences for today's NASA technology such as the ISS. This course of action would provide the opportunity to produce, revise, and refine the technologies that we will use to allow us all to go in 2020. The group also thought extensively about tools and their affordances. The NASA virtual world would need to support transactions by experts, novices, and dilettante. Research would determine the degree that tools off-load intelligence, knowledge, and procedural requirements. All world citizens might be able to assist in the solution of problems related to NASA science.

The group also discussed the Metaverse Roadmap Overview as a means of predicting where technology will be in 2020. Here, Metaverse refers to the convergence of virtually-enhanced physical reality and physically persistent virtual space. It is a fusion of both, while allowing users to experience it as either (http://www.metaverseroadmap.org/overview/).

One potential strategy is to look at how to improve on what NASA is currently doing in virtual world technologies. It was noted that everything that will be mass market by 2020 is in existence today. Recent examples include the simulations that have been done for the ISS and LCROSS. We should get these simulations into the public domain and allow the public to interact with them. We need to communicate to NASA leadership that virtual worlds can augment NASA's mission and, therefore, should be matured to a higher technology readiness level.

VI. Next Steps with Pete Worden:

ARC Center Director Pete Worden addressing the workshop (Photo courtesy of Bruce Damer)

The final session of the workshop was chaired by Pete Worden, and was focused on questions of how we proceed forward to make virtual worlds an effective tool to facilitate public understanding and support for NASA's mission. Can participatory exploration increase the productivity of NASA missions? We need to use virtual world technology to both excite and educate the next generation of young people. We need greater capability of putting data from missions into cross-referenced format that can lead to greater science return.

A key question is how to further develop the enabling technologies for virtual worlds. Although resources within NASA are limited, can we leverage off a robust industry? and how do we do so without being US centric, but instead global-centric? Also, how can we support NASA CoLab in their effort to promote collaboration between communities inside and outside of NASA, to publicize NASA programs, and to promote open source software?

There was some discussion surrounding NASA Ames' relationship with Google. Pete Worden indicated that this relationship fits within NASA's assigned duty to midwife technology and space exploration. The Space Act agreement provides the needed mechanism for NASA to enter into collaborations with companies. Collaborations between NASA Ames and Google make sense for a number of reasons. First there are common interests in disciplines like Earth Science and Information Technology (IT). ARC is the lead center for IT for the agency and therefore in a position to pioneer relationships with IT companies. Google's leadership has a strong interest in space, as evidenced by their sponsoring the Lunar X prize. Pete Worden also indicated that Ames is trying to build collaborations with other companies, such as Symantec Corporation, Sun Microsystems, and Microsoft Corporation.

There was discussion centered on how virtual worlds could be populated with better models and data. For example, it would be useful to have high-fidelity models of the ISS available, not just in *Second Life*, but also on other platforms. There was an action to see how Ames Research Center and Johnson Space Center could partner to make this a reality. Larry Smarr suggested a summer internship program focused on adding functionality to virtual worlds. This could excite young people and be a potential source of recruiting talent. Another idea is to engage the public for certain tasks analogous to the Search for Extra-Terrestrial Intelligence (SETI) at home virtual super-computer model.

Considerable discussion was focused on how we can use virtual worlds to excite young people. Pete Worden discussed the American Student Moon Orbiter (ASMO) program, which is designed with the fundamental premise that university participants, and not NASA, would design, build, launch, operate, and own the ASMO spacecraft and its payloads. This program gives people hands-on experience and teaches them how to work internationally as well. This is a departure from the very controlled engineering environment at NASA, as control is given up to the students with NASA serving in a mentor role. This gives the students ownership of the program and hopefully creates an air of mysticism missing in most NASA programs. Carolyn Summers suggested as a means of engaging the public, putting a fish-eye camera on ISS that could be controlled from the web. Crista Lopes commented on the need for a standard infrastructure, and noted that students were really engaged when building things. Bob Ketner noted that simple things such as contests, software development kits etc., are good ways to engage people. Stan Trevena suggested that NASA should create a system where kids gain points for proving levels of proficiency in topics. Begin with low-level assignments and measure their progress.

VII. Final Comments

Virtual worlds are in a period of rapid growth and have wide applicability for video games, social interaction, training and simulation, business collaboration, and education. MMO games have the potential to engage the community in the participatory exploration of space. In the forty year history of virtual worlds, NASA Ames played a key role, with some of the earliest virtual tele-operations, 3D graphics, and graphics associated with immersive wind-tunnel research. Ames and NASA, in general, has a continued role to play in the evolution of virtual worlds. As this workshop demonstrated, it is truly a great convergence of cyberspace… and outerspace!

All websites sited in this report were accessible as of April 28, 2009.

VIII. Attendee Comments and Follow-On Activities

After the workshop was over, we created a wiki to capture additional thoughts by the attendees and to produce a forum to describe follow-on collaborations.

VIII.1 Comments on aspects of the workshop

Debbie Denise Reese provided her insights into the challenges of designing MMO games that are both educational and fun (engaging for the player). Content fidelity is an important aspect when the goal of the game is learning rather than entertainment. She noted that Ron Creel's team has the requisite and unique content expertise for their game. However, in addition to content expertise, game design expertise is requisite for design of a game that incorporates gameplay and structures a game system to support and motivate gameplay targeted toward player construction of targeted knowledge. The LUROVA simulation would benefit from adding experienced game designers to their team, along with staff that can mediate between the content experts and the game designers. In other words, teams must include content, game, and pedagogy expertise—as well as individuals with the expertise to broker/mediate/lead the team to achieve an optimal game experience. This was achieved with the MMO game *Spore*, albeit with considerable investment of funds.

Debbie Denise Reese also provided comments about the terms cognitive outsourcing and off-loading. The term off-loading has been defined as a process through which "mediating structures organize and constrain activity" (Pea, 1997, p. 48). Off-loading is a component of a division of labor in which the other (whether machine, tool, person, environment, etc.) carries part of the cognitive load. The trade-off of off-loading is an increase in efficiency and accomplishment without concurrent increase in understanding. In contrast, environments (in our case, virtual environments) targeting learning might concentrate on tools that scaffold understanding and knowledge/skill growth. Scaffolding is an instructional technique whereby the teacher or learning environment supports (e.g., models, cues, job aids, etc.) the desired learning strategy or task, then gradually shifts responsibility to the students. Software environments provide scaffolding when they offer help agents like the Microsoft® Word paperclip or the *Wii™ Legend of Zelda: Twilight Princess* fairy. Pea[1] called for "reflectively and intentionally distributed intelligence in education, where learners are inventors of distributed-intelligence-as-tool, rather than receivers of intelligence–as-substance" (Pea, 1997, p. 82). Speakers at the Ames Virtual Worlds workshop supported this participatory vision for game and virtual worlds. At the same time, designers of NASA's virtual environments (such as those proposed by this workshop's 2020 Vision breakout group) must carefully consider situations, learner/participant characteristics, and learning/participatory goals, to determine the parameters (e.g., when and for whom) under which aspects of the environment should off-load and/or scaffold.

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[1]Pea, R. D. (1997). Practices of distributed intelligence and designs for education. In G. Salomon (Ed.), Distributed cognitions: Psychological and educational considerations (pp. 47-87). New York: Cambridge University Press.

VIII.2 Follow-On Actions

A collaboration that came directly out of the workshop was an effort to provide high fidelity data for Calit2's immersive virtual world systems. Data from the Mars Exploration Rovers, the Mars Reconnaissance Orbiter, and the Apollo Moon missions were uploaded and displayed in the CAVE at Calit2. Standing in the CAVE with a GPS helmet gave the viewer the feeling of standing on the Martian landscape. From that activity, the NASA Lunar Science Institute (NLSI) has built a hyperwall, a 3x3 multitiled display system that runs on Calit2's ROCKS open source Linux cluster computing software connected at 10GB to the NASA Research and Engineering Network (NREN). Using these tiled displays, scientists are able to visualize complex data systems allowing effective collaborations both in-person and between remote teams. As a follow-up to this sharing of data between Calit2 and NASA Ames, Michael Sims and Laurence Edwards of NASA Ames Exploration Technologies and Estelle Dodson of the NASA Astrobiology and NASA Lunar Science Institutes (NAI and NLSI respectively) managed at ARC, wrote a white paper about high definition, large scale displays connected to advanced research networks.

Another outcome of the workshop is a virtual component of the NASA Astrobiology Institute's Astrobiology (NAI) Graduate Student Conference (AbGradCon) to be held in July 2009. Talks at AbGradCon will be streamed into *Second Life* and a virtual poster session will be held in a virtual environment called, "Qwak" (http://www.qwaq.com/).

The NAI and NLSI are installing high definition videoconferencing systems at all of their team sites to promote communication, collaboration and community building between distributed research teams. The two virtual institutes contain 21 teams distributed in 150 locations. Virtual worlds and immersive environments may play a critical role in their communication, interdisciplinary insights, and productivity.

Since the Virtual Worlds and Immersive Environments Workshop, Google Mars has also improved their capabilities for image viewing, adding 3D immersive capabilities from data obtained through the Mars Reconnaissance Orbiter. These capabilities enhance the public's experience of Mars exploration, in addition to providing scientists a meaningful and contextual way to share data.

Larry Smarr connecting with Pete Worden, which led to support by NASA ARC providing Mars date for Calit2's immersive VR systems (Photo courtesy of Bruce Damer)

Closing view: Original Virtual Worlds. Paintings of Gerard O'Neill space colonies displayed for the benefit of the workshop (from the Summer 1975 workshop at NASA Ames) (Photo courtesy of Bruce Damer)

Final good-byes from the Virtual Worlds Workshop! (Photo courtesy of Bruce Damer)

Acronyms

3D	Three Dimensional
API	Application Programming Interface
ARC	Ames Research Center
ASMO	American Student Moon Orbiter
CEV	Crew Exploration Vehicle
EDS	Earth Departure Stage
EVA	Extra Vehicular Activity
GB	Gigabyte
HRSC	High/Super Resolution Stereo Color Camera
IMAX	Image MAXimum
ISO	International Organization for Standardization
ISS	International Space Station
IT	Information Technology
JPL	Jet Propulsion Laboratory
LCROSS	Lunar Crater Observation and Sensing Satellite
LM	Lunar Module
LRC	Lunar Racing Championship
LROC	Lunar Reconnaissance Orbiter Camera
LRV	Lunar Rover Vehicle
LSAM	Lunar Surface Access Module
LUROVA	LUnar ROVing Adventure
MB	Megabyte
MMO	Massively Multiplayer Online

Acronyms

MMOE	Massively Multiplayer Online Environment
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memoranda of Understanding
MRO	Mars Reconnaissance Orbiter
MSFC	Marshall Space Flight Center
NASA	National Space and Aeronautics Agency
NEO	Near Earth Object
NSF	National Science Foundation
NSS	National Space Society
RADE	Rapid Application Development
RASCL	Rapid Application Scripting Language
RFP	Request for Proposal
SBIR	Small Business Innovation Research
SDK	Software Developer's Kit
SETI	Search for Extra-Terrestrial Intelligence
SOHO	Solar and Heliospheric Observatory
SOLIS	Society for Life in Space
TB	Terabyte
TLI	Trans Lunar Injection
USRA	Universities Space Research Association
VE	Virtual Environment
VR	Virtual Reality
XML	Extensible Markup Language

Agenda

Virtual Worlds and Immersive Environments (A NASA-Ames Workshop)

		DAY ONE Sat, January 26th	
Time	**Dur.min**	**Description**	**Speakers & Discussion leaders**
8:00	30	Breakfast	
8:30	5	Logistics	Stephanie Langhoff
8:35	10	Welcome/objectives	Pete Worden
8:45	15	Introduction of participants	
Remote Exploration			Jeanne Holm
9:00	30	FOUNDATIONAL TALK: Cyberspace Meets Outerspace	Bruce Damer
9:30	30	Discussion	
10:00	15	Bringing Planetary Content into Virtual Worlds	Matt Hancher
10:15	15	Discussion	
10:30	15	Break	
10:45	15	X3D and Networked Interoperability	Alan Hudson
11:00	15	Discussion	
11:15	15	LUROVA: "Edutainment"	Ron Creel
11:30	15	Discussion	
11:45	15	Ongoing work for the NASA Constellation Architecture Integration team	Tom Cochrane
12:00	15	Discussion	
12:15	60	Lunch	
We All Get to Go			**Bruce Damer**
13:15	30	FOUNDATIONAL TALK: Exploring a Toy Galaxy	Will Wright
13:45	30	Discussion	
14:15	15	The SciFair Model: Supporting Teams of Kids Creating Virtual Worlds	Margaret Corbit
14:30	15	Discussion	
14:45	15	Educational Applications and Pedagogical Underpinnings of Virtual Worlds	Daniel Laughlin
15:00	15	Discussion	
15:15	15	Break	
15:30	15	K-20 education: Distance Learning and Collaboration using *Second Life*	Stan Trevena, Cathy Arreguin
15:45	15	Discussion	
16:00	15	Exploring the Multiverse	Corey Bridges
16:15	15	Discussion	
16:30	15	Opening the Universe	Khal Shariff
16:45	15	Discussion	
17:00	15	New Methods in Simulation Applications for Education: A Real World Example, "The Lunar Racing Championship" Game	Mary Duda
17:15	15	Discussion	
17:30	15	From 2-D to 3D Web: The Science Center in *Second Life*	Rob Rothfarb
17:45	15	Discussion	
18:00		Adjorn	
19:00		DINNER: Chef Chu's, 1067 N San Antonio Rd, Los Altos	

Agenda

Time	Dur. (min)	DAY TWO Sun., January 27th Description	Speakers & Discussion leaders
8:00	30	Breakfast	
Become the Data			**Estelle Dodson**
8:30	30	FOUNDATIONAL TALK: Remote Telepresence for Exploring Virtual Worlds	Larry Smarr
9:00	30	Discussion	
9:30	15	Why Open Protocols Matter	Crista Lopes
9:45	15	Discussion	
10:00	15	Break	
10:15	15	Life After the Orphidnet	Rudy Rucker
10:30	15	Discussion	
10:45	15	How Virtual Worlds May Augment Collaboration	Henrick Bennetsen
11:00	15	Discussion	
11:15	15	Living Beyond Ourselves: How the Next Crewed Mission to the Moon Could Transform the Way Humanity Experienes Life	George Whitesides
11:30	15	Discussion	
11:45	15	Democratizing the Universe	Ed Lantz
12:00	15	Discussion	
12:15	15	Shrinking Space: Designs for Augmented Exploration	Bob Ketner
12:30	15	Discussion	
Breakout Sessions			**Jessy Cowan-Sharp**
12:45	5	Introduction to Breakout Sessions: (1) How could we best use virtual worlds environments to support for LCROSS and other near term NASA missions? (2) What can NASA do to create a viable community of people and companies developing virtual worlds technologies for space? Grants? Cooperative agreements? Contests/challenges? (3) 2020 Vision: how will virtual worlds be used in the exploration of space in the year 2020 in support of planning and operations?	Chairs: Matt Hancher (1) Margaret Corbit (2) George Whitesides (3)
12:50	60	Working Lunch in Breakout Sessions	
13:50	60	Continuation of Breakout Sessions	
14:50	15	Break	
15:05	30	Reporting of breakout groups	Session Chairs
15:35	30	DISCUSSION: Research priorities-where do we go from here?	Pete Worden
16:05		Adjourn	

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14. ABSTRACT

The workshop revolved around three framing ideas or scenarios about the evolution of virtual environments:

1. Remote exploration: The ability to create high fidelity environments rendered from external data or models such that exploration, design and analysis that is truly interoperable with the physical world can take place within them.

2. We all get to go: The ability to engage anyone in being a part of or contributing to an experience (such as a space mission), no matter their training or location. It is the creation of a new paradigm for education, outreach, and the conduct of science in society that is truly participatory.

3. Become the data: A vision of a future where boundaries between the physical and the virtual have ceased to be meaningful. What would this future look like? Is this plausible? Is it desirable? Why and why not?

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